Atlantic Canada Guidelines for the Supply, Treatment, Storage, Distribution, and Operation of Drinking Water Supply Systems

September 2004

Prepared by:

CBCL LIMITED
Consulting Engineers

Coordinated by the Atlantic Canada Water Works Association (ACWWA) in association with the four Atlantic Canada Provinces

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PURPOSE AND USE OF MANUAL

Purpose

The purpose of the *Atlantic Canada Guidelines for the Supply, Treatment, Storage, Distribution and Operation of Drinking Water Supply Systems* is to provide a guide for the development of water supply projects in Atlantic Canada.

The document is intended to serve as a guide in the evaluation of water supplies, and for the design and preparation of plans and specifications for projects. The document will suggest limiting values for items upon which an evaluation of such plans and specifications may be made by the regulator, and will establish, as far is practical, uniformity of practice.

The document should be considered to be a companion to the *Atlantic Canada Standards and Guidelines Manual for the Collection, Treatment and Disposal of Sanitary Sewage.*

Limitations

Users of the Manual are advised that requirements for specific issues such as filtration, equipment redundancy, and disinfection are not uniform among the Atlantic Canada provinces, and that the appropriate regulator should be contacted prior to, or during, an investigation to discuss specific key requirements.

Approval Process

Chapter 1 of the Manual provides an overview of the approval process generally used by the regulators. Proponents are advised, however, to familiarize themselves with the requirements of all legislation dealing with water supply projects in the province where the work is to be undertaken.

The respective provincial legislation, guidelines, and/or contacts may be accessed as follows:

New Brunswick Department of the Environment and Local Government:

Director
Stewardship Branch
NB Department of Environment & Local Government
20 McGloin Street
Fredericton, NB
E3A 5T8

(506) 453-7945 (phone)
(506) 453-2390 (fax)

Newfoundland and Labrador Department of Environment and Conservation:
Manger
Community Water and Wastewater Section
Water Resources Management Division
PO Box 8700
St. John's, NL A1B 4J6
Contact 709-729-2535
Fax: 709-729-0320

Nova Scotia Department of Environment and Labour:
Water and Wastewater Branch
5151 Terminal Road, 5th Floor, PO Box 697
Halifax, NS B3J 2T8
Contact 902-424-5300
Fax: 902-424-0503

Prince Edward Island Department of Environment and Energy:
Water Management
11 Kent St., PO Box 2000
Charlottetown, PEI C1A 7N8
Contact 902-368-5000
Fax: 902-368-5830

Innovation

The Manual should be used as a guide, and therefore is not intended to limit innovation on the part of proponents. Where the designer can show that alternate approaches can produce the desirable results, such approaches may be considered for approval.

Definition of Terms

The terms used in the manual reflect generally used definitions in the water industry. Users of the Manual are referred to the American Water Works Association (AWWA) "Drinking Water Dictionary" for a comprehensive definition of water related terms.

Policy/Position Papers

There are a wide range of issues which must be dealt with in the upgrading of existing water systems or the implementation of new systems. Not all of these issues are easily categorized and addressed as a guideline. In some cases technical aspects of the issues are still emerging, while others may require greater discussion regarding the context in which they may be used or dealt with.

AWWA and the Canadian Water and Wastewater Association (CWWA) have developed policy/position papers that reflect the current state of knowledge, experience and best practices on a variety of topics. Users of the Manual are encouraged to review AWWA and CWWA policy/position papers at the following:

AWWA: http://www.awwa.org/about/oandc/officialdocs/AWWASTAT.cfm
http://www.awwa.org/Advocacy/govtaff/govpol.cfm

CWWA: http://www.cwwa.ca/policy_e.asp
http://www.cwwa.ca/position_e.asp

Reference Material

In developing the Manual, material from outside sources was reviewed, and guidelines appropriate for conditions in Atlantic Canada were adopted. In some cases, multiple sources are referenced in the Manual, pending responses from the industry

A list of references used is attached as Appendix A.

Feedback

The development of the *Atlantic Canada Guidelines for the Supply, Treatment, Storage, Distribution and Operation of Drinking Water Supply Systems* was coordinated by the Atlantic Canada Water Works Association (ACWWA), in coordination with the four Atlantic Canada provinces.

The document was developed under contract by a team of qualified engineers and hydrogeologists with substantial experience in Atlantic Canada, supported by a review committee consisting of representatives from the provincial departments and two utilities. The committee members include:

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Andre Chenard, NB Dept. of Environment &Local Government

John Eisnor, NS Dept. of Environment & Labour

Ensor Nicholson, City of Moncton

Tom Gorman, Halifax Regional Water Commission

Jamie Hannam, Halifax Regional Water Commission, Chair

The document is distributed as a "first edition" with ACWWA co-ordinating a review after a period of initial use.

Conflicts

Conflicting statements may have survived the review process. Should conflicting statements be found, readers are directed to contact the regulatory authority for the appropriate jurisdiction for clarification.

Comments

Comments on the documents should be forwarded to the following:

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CHAPTER 1.0 APPROVAL REQUIREMENTS AND PROCEDURES 1-1

1.1 GENERAL OVERVIEW OF APPROVALS 1-1

1.1.1 Summary of Approval Process 1-1
1.1.2 Review by Other Jurisdictions 1-4

1.2 OUTLINE OF APPROVAL PROCESS 1-4

1.2.1 Pre-Consultation 1-4
1.2.2 Pre-Design (Technical) Report 1-4
1.2.2.1 Purpose of a Pre-Design Report 1-4
1.2.2.2 Contents of a Pre-Design Report 1-6
1.2.2.3 Key Components of a Pre-Design Evaluation 1-11
1.2.2.3.1 Future Population and Commercial/Industrial Uses .. 1-11
1.2.2.3.2 Water Demand Projections 1-11
1.2.2.3.3 Design Criteria 1-12
1.2.2.3.4 Site Selection of Treatment Facility 1-12
1.2.2.3.5 Conceptual Layout of Treatment Plant 1-12
1.2.2.3.6 Ancillary Equipment and Infrastructure 1-13
1.2.2.3.7 Route Selection of Transmission Mains 1-13
1.2.2.3.8 Site Selection of Water Storage Reservoirs 1-13
1.2.2.3.9 Cost Estimates and Financing 1-14
1.2.3 Review of Pre-Design Report 1-15
1.2.4 Acceptance of Pre-Design Report 1-15
1.2.5 Detailed Design Submission 1-15
1.2.5.1 General 1-15
1.2.5.2 Plans 1-16
1.2.5.3 Technical Specifications 1-18
1.2.5.4 Design Brief 1-18
1.2.5.4.1 General Information 1-18
1.2.5.4.2 Extent of Water Works System 1-19
1.2.5.4.3 Soil, Groundwater Conditions, and Foundation Problems 1-19
1.2.5.4.4 Water Demands 1-19
1.2.5.4.5 Hydraulic Evaluations of Transmission and Distribution Systems 1-19
1.2.5.4.6 Sources of Water Supply 1-19
1.2.5.4.7 Design Criteria for Water Treatment Plants 1-20
1.2.5.4.8 Automation 1-21
1.2.5.4.9 Requirements for Operation During Construction . 1-21
1.2.6 Review of Design Submission 1-22
1.2.7 Issue of Approval/ Permit to Construct 1-22
1.2.8 Post Construction Report/Certificate of Compliance 1-23

1.2.9 Issue of Approval/Permit to Operate 1-23
1.3 MONITORING AND RECORDING REQUIREMENTS 1-24
1.4 REPORTING REQUIREMENTS 1-24
1.5 FACILITY CLASSIFICATION AND OPERATOR CERTIFICATION 1-24
1.6 OWNER RESPONSIBILITY 1-24
1.7 REGULATOR RESPONSIBILITY 1-25
CHAPTER 2.0 SOURCE WATER DEVELOPMENT 2-1
2.1 GENERAL 2-1
2.2 SURFACE WATER 2-1
2.2.1 Quantity Assessment 2-1
2.2.2 Watershed Delineation and Protection 2-2
2.2.2.1 Watershed Delineation 2-2
2.2.2.2 Watershed Protection 2-3
2.2.3 Water Treatment 2-3
2.2.3.1 Laboratory Scale Testing Program 2-3
2.2.3.2 Pilot Scale Testing Program 2-3
2.2.4 Required Intake Facility 2-5
2.2.5 Impoundments and Reservoirs 2-6
2.3 GROUNDWATER SUPPLY 2-6
2.3.1 Location 2-6
2.3.2 Exploration Program 2-7
2.3.3 Well and Aquifer Yield Hydraulic Testing 2-9
2.3.4 Groundwater Quality 2-11
2.3.5 Water Treatment 2-12
2.3.6 Well Construction 2-12
2.3.6.1 Casing 2-14
2.3.6.2 Stabilization Liners 2-15
2.3.6.3 Grouting 2-16
2.3.6.4 Well Screens 2-16
2.3.6.5 Well Development 2-16
2.3.6.6 Disinfection 2-16
2.3.6.7 Abandonment 2-17
2.3.7 Pump Hydraulics 2-17
2.3.8 Wellhead Requirements 2-18
2.3.8.1 Discharge Piping 2-19
2.3.8.2 Pitless Well Head Completion 2-19
2.3.9 Aquifer Protection Monitoring 2-19

2.3.9.1 Observation Wells 2-20
2.3.9.2 Well Head Protection Plan 2-20
2.3.10 Well or Well Field Commissioning 2-21

2.4 SOURCE WATER PROTECTION 2-21

CHAPTER 3.0 DESIGN OF WATER TREATMENT FACILITIES 3-1

3.1 DESIGN BASIS 3-1

3.1.1 Design Flows 3-1
3.1.2 Target Contaminants and Process Selection 3-1
3.1.3 General Redundancy Requirements 3-1

3.2 SITE SELECTION 3-2

3.2.1 General 3-2
3.2.2 Proximity to Existing Infrastructure 3-2
3.2.3 Separation Distances and Future Site Expansion 3-3
3.2.4 Hydraulic Grade Lines 3-3
3.2.5 Topography and Geotechnical Investigations 3-3
3.2.6 Land Ownership 3-4
3.2.7 Site-Related Life-cycle Costs 3-4

3.3 LAYOUTS 3-5

3.3.1 Site Layout 3-5
3.3.2 Building/Plant Layout 3-5
3.3.3 Provisions for Future Expansion 3-6

3.4 P&ID DIAGRAMS AND PLANT CONTROL 3-7

3.5 STANDY-BY POWER 3-7

3.6 CHEMICAL FEED FACILITIES 3-7

3.6.1 General 3-7
3.6.1.1 Plans and Specifications 3-7
3.6.1.2 Chemical Application 3-8
3.6.1.3 Equipment Design 3-8
3.6.2 Chemical Feed System Design 3-9
3.6.2.1 Number of Chemical Feed Systems 3-9
3.6.2.2 Control of Chemical Feed Systems 3-9
3.6.2.3 Dry Chemical Feeders 3-10
3.6.2.4 Positive Displacement Metering Pumps 3-10
3.6.2.5 Siphon Control 3-11
3.6.2.6 Cross-Connection Control 3-11
3.6.2.7 Make-up Water Supply 3-11
3.6.2.8 Chemical Storage Requirements 3-12
3.6.2.9 Solution and Mixing Tanks 3-13

3.6.2.10 Day Tanks 3-13
3.6.2.11 Solution Transport 3-14
3.6.2.12 Handling 3-15
3.6.3 Chemicals 3-15
3.6.3.1 General 3-15
3.6.3.2 Chlorine Gas 3-16
3.6.3.3 Acids and Caustics 3-18
3.6.3.4 Sodium Chlorite for Chlorine Dioxide Generation 3-18

3.7 PLANT FACILITIES 3-19

3.7.1 Maintenance and Storage Facilities 3-19
3.7.2 Offices and Control Area 3-19
3.7.3 Washroom Facilities 3-19
3.7.4 Lunchrooms 3-19
3.7.5 Facility Water Supply 3-19

3.8 LABORATORY FACILITIES 3-19

3.8.1 General 3-20
3.8.2 Testing Equipment 3-20
3.8.3 Physical Facilities 3-21

3.9 MONITORING 3-21

3.9.1 Sample Taps and Locations 3-21
3.9.2 On-line Monitoring Equipment 3-21
3.9.3 Meters 3-22

3.10 OPERATIONS AND SAFETY 3-22

3.10.1 Operation and Maintenance Manuals 3-22
3.10.2 Safety and Hazardous Materials 3-22

3.11 FACILITY CONSTRUCTION 3-23

3.11.1 Basic Materials of Construction 3-23
3.11.1.1 Concrete Tankage 3-23
3.11.1.2 Prefabricated Tankage 3-23
3.11.1.3 Superstructure 3-23
3.11.1.4 Access, Ladders, Catwalks and Stairways 3-24
3.11.2 Valves and Piping Materials 3-24

3.12 LABELING AND COLOUR CODING 3-24

3.12.1 Commissioning and Testing 3-25
3.12.2 Security 3-25

3.13 REMOTE OPERATION OF FACILITIES 3-26

3.14 OTHER CONSIDERATIONS 3-26

CHAPTER 4.0 DESIGN OF WATER TREATMENT PROCESSES 4-1

4.1 GENERAL 4-1

4.2 PRESEDIMENTATION AND SCREENING 4-1
- 4.2.1 Pre-sedimentation 4-1
- 4.2.2 Screening 4-1

4.3 COAGULATION / FLOCCULATION PROCESS 4-2
- 4.3.1 General Process Description 4-2
  - 4.3.1.1 Coagulation 4-2
  - 4.3.1.2 Flocculation 4-3
- 4.3.2 Rapid Mixing 4-3
  - 4.3.2.1 Chemical Injection 4-3
  - 4.3.2.2 In-line Static Mixers 4-3
  - 4.3.2.3 In-line Mechanical Mixers 4-3
  - 4.3.2.4 Paddle-Type Rapid Mixer 4-4
- 4.3.3 Flocculation 4-4
  - 4.3.3.1 Flocculation Basins 4-4
  - 4.3.3.2 Flocculators 4-5

4.4 CLARIFICATION 4-6
- 4.4.1 Sedimentation 4-6
  - 4.4.1.1 General 4-6
  - 4.4.1.2 Conventional Sedimentation 4-8
  - 4.4.1.3 Plate and Tube Sedimentation 4-8
  - 4.4.1.4 Solids Contact Clarifiers 4-9
  - 4.4.1.5 Upflow Sludge Blanket Clarifiers 4-10
  - 4.4.1.6 Ballasted Flocculation 4-11
- 4.4.2 Dissolved Air Flotation 4-11
  - 4.4.2.1 General 4-11
  - 4.4.2.2 Design Criteria 4-12
- 4.4.3 Adsorption Clarification 4-13

4.5 FILTRATION 4-14
- 4.5.1 Rapid Rate Gravity Filtration 4-15
  - 4.5.1.1 Pretreatment 4-15
  - 4.5.1.2 Rate of Filtration 4-15
  - 4.5.1.3 Number of Units and Redundancy 4-15
  - 4.5.1.4 Headloss and Control 4-15
  - 4.5.1.5 Structural and Hydraulic Details 4-16
  - 4.5.1.6 Filter Media 4-17
  - 4.5.1.7 Filter Underdrains 4-19
  - 4.5.1.8 Surface Wash or Subsurface Wash 4-20

4.5.1.9 Filter to Waste 4-20
4.5.1.10 On-line Turbidity Monitoring 4-20
4.5.1.11 Filter Appurtenances 4-20
4.5.1.12 Backwashing 4-21
4.5.1.13 Air Scour 4-22
4.5.2 Rapid Rate Pressure Filtration 4-23
4.5.2.1 Rate of Filtration 4-23
4.5.2.2 Additional Requirements 4-23
4.5.3 Direct Filtration 4-24
4.5.3.1 Piloting and Approval Requirements 4-24
4.5.3.2 Pretreatment 4-25
4.5.3.3 General Design 4-25
4.5.3.4 Rate of Filtration 4-25
4.5.4 Diatomaceous Earth Filtration 4-26
4.5.4.1 Piloting Requirements 4-26
4.5.4.2 General Design 4-26
4.5.4.3 Treated Water Storage 4-26
4.5.4.4 Number of Units and Redundancy 4-26
4.5.4.5 Pre-coat 4-26
4.5.4.6 Body Feed 4-26
4.5.4.7 Filtration 4-27
4.5.4.8 Appurtenances 4-27
4.5.5 Slow Sand Filtration 4-28
4.5.5.1 Application 4-28
4.5.5.2 Number and Redundancy 4-28
4.5.5.3 General Design 4-28
4.5.5.4 Rate of Filtration 4-29
4.5.5.5 Underdrains 4-29
4.5.5.6 Filter Media 4-29
4.5.5.7 Water Depth and Headloss 4-30
4.5.5.8 Appurtenances 4-30
4.5.5.9 Scraping and Ripening 4-30
4.5.6 Biological Filtration 4-30
4.5.6.1 General Design 4-30
4.5.6.2 Piloting Requirements 4-31
4.5.7 Membrane Filtration 4-31
4.5.7.1 Applicable Processes 4-31
4.5.7.2 Number and Redundancy 4-32
4.5.7.3 Piloting Requirements 4-32
4.5.7.4 Membrane Materials 4-32
4.5.7.5 Membrane Configurations 4-33
4.5.7.6 Design Criteria 4-33

4.5.7.7 Integrity Testing 4-34
4.5.7.8 Redundancy 4-34

4.6 DISINFECTION 4-34

4.6.1 Chlorination 4-34
4.6.1.1 Inactivation Requirements 4-34
4.6.1.2 Inactivation Requirements 4-36
4.6.1.3 Residual Chlorine 4-36
4.6.1.4 Chlorination Equipment 4-36
4.6.1.5 General Guidelines 4-38
4.6.2 Alternate Disinfectants 4-39
4.6.2.1 Types of Alternate Disinfectants 4-39
4.6.2.2 Process Descriptions 4-40
4.6.2.3 Contact Time 4-42
4.6.2.4 Disinfectant Residual 4-42
4.6.2.5 Piloting Requirements 4-42

4.7 SOFTENING 4-43

4.7.1 Lime or Lime-Soda Processes 4-43
4.7.2 Cation Exchange Processes 4-43

4.8 AERATION 4-45

4.8.1 Natural Draft Aeration 4-46
4.8.2 Forced or Induced Draft Aeration 4-46
4.8.3 Spray Aeration 4-47
4.8.4 Pressure Aeration 4-48
4.8.5 Packed Tower Aeration 4-48
4.8.5.1 Piloting Requirements 4-48
4.8.5.2 Process Design 4-48
4.8.5.3 Materials of Construction 4-49
4.8.5.4 Water Flow System 4-49
4.8.5.5 Air Flow System 4-50
4.8.5.6 Other 4-50
4.8.6 Other Methods of Aeration 4-51
4.8.7 Protection of Aerators 4-51
4.8.8 Disinfection 4-51
4.8.9 By-Pass 4-51
4.8.10 Corrosion Control 4-52
4.8.11 Quality Control 4-52

4.9 IRON AND MANGANESE CONTROL 4-52

4.9.1 Removal by Oxidation, Detention and Filtration 4-52
4.9.2 Removal by Lime-Soda Softening 4-52
4.9.3 Removal by Manganese Coated Media Filtration 4-52

4.9.3.1 Oxidant Addition 4-53
4.9.3.2 Media 4-53
4.9.3.3 Design 4-53
4.9.3.4 Sample Taps 4-54
4.9.4 Proprietary Media 4-54
4.9.5 Removal by Ion Exchange 4-54
4.9.6 Treatment by Sequestration 4-54
4.9.6.1 Polyphosphates Sequestration 4-54
4.9.6.2 Sodium Silicates Sequestration 4-54
4.9.7 Sampling Taps 4-55
4.9.8 Testing 4-55

4.10 FLUORIDATION 4-55

4.10.1 Naturally Occurring Fluoride 4-55
4.10.2 Artificial Fluoridation 4-55
4.10.2.1 Fluoride Compound Storage 4-55
4.10.2.2 Chemical Feed Equipment and Methods 4-56
4.10.2.3 Secondary Controls 4-57
4.10.2.4 Protective Equipment 4-57
4.10.2.5 Dust Control 4-57
4.10.2.6 Testing Equipment 4-58

4.11 STABILIZATION AND CORROSION CONTROL 4-58

4.11.1 Carbon Dioxide Addition 4-58
4.11.2 Acid Addition 4-58
4.11.3 Phosphates 4-58
4.11.4 Split Treatment 4-59
4.11.5 Alkali Addition 4-59
4.11.6 Carbon Dioxide Reduction by Aeration 4-59
4.11.7 Water Unstable Due to Biochemical Activity 4-60
4.11.8 Testing 4-60

4.12 TASTE AND ODOUR CONTROL 4-60

4.12.1 Chlorination 4-60
4.12.2 Chlorine Dioxide 4-60
4.12.3 Powdered Activated Carbon 4-60
4.12.4 Granular Activated Carbon 4-61
4.12.5 Aeration 4-61
4.12.6 Potassium Permanganate 4-61
4.12.7 Ozone 4-61
4.12.8 Piloting Requirements 4-61

4.13 WASTE HANDLING 4-61

4.13.1 General 4-62

4.13.2 Sanitary Waste 4-62
4.13.3 Water Treatment Plant Residuals 4-62
4.13.3.1 Brine Waste 4-62
4.13.3.2 Lime Softening Sludge 4-62
4.13.3.3 Coagulation Sludges 4-63
4.13.3.4 Spent Filter Backwash Water 4-63
4.13.4 Quantity 4-63
4.13.5 Direct Discharge to Sewer 4-63
4.13.6 Waste Treatment 4-63
4.13.6.1 Waste Equalization and Mixing 4-64
4.13.6.2 Lagoon Treatment 4-64
4.13.6.3 Thickening and Sedimentation 4-65
4.13.6.4 Dissolved Air Flotation 4-65
4.13.6.5 Membranes 4-65
4.13.6.6 Polymer Addition 4-65
4.13.6.7 Iron and Manganese Wastes 4-66
4.13.7 Spent Filter Backwash Water Recycling 4-68
4.13.8 Dewatering 4-68
4.13.8.1 Air/Gravity Drying Processes 4-69
4.13.8.2 Mechanical Dewatering Processes 4-69
4.13.8.3 Comparison of Dewatering Processes 4-70
4.13.9 Sludge Disposal 4-70

4.14 EMERGING TECHNOLOGIES 4-71

CHAPTER 5.0 PUMPING FACILITIES 5-1

5.1 FACILITY TYPES 5-1
5.1.1 Raw Water Pumping Facility 5-1
5.1.2 Booster Pumping Facility 5-1
5.1.3 Fire Pumping Facility 5-1

5.2 FACILITY CONSTRUCTION 5-2
5.2.1 General 5-2
5.2.2 Location 5-2
5.2.2.1 Site Protection 5-2
5.2.3 Pumping Stations 5-2
5.2.4 Suction Well 5-3
5.2.5 Equipment Servicing 5-3
5.2.6 Stairways and Ladders 5-4
5.2.7 Heating 5-4
5.2.8 Ventilation 5-4
5.2.9 Dehumidification 5-4
5.2.10 Lighting 5-5

5.2.11 Sanitary and Other Conveniences 5-5

5.3 PUMPS 5-5

5.3.1 Selection 5-5
5.3.1.1 Water Quality 5-5
5.3.1.2 System Head Curves 5-6
5.3.1.3 Modes of Operation 5-6
5.3.1.4 Pump Flow / Head Margins 5-6
5.3.1.5 Type of Pump Control 5-6
5.3.1.6 Future System Changes 5-7
5.3.2 Suction Lift Pumps 5-7
5.3.3 Priming 5-7

5.4 BOOSTER PUMPS 5-7

5.4.1 Metering 5-8
5.4.2 Individual Home Booster Pumps 5-8

5.5 AUTOMATIC AND REMOTE CONTROLLED STATIONS 5-8

5.6 APPURTENANCES 5-8

5.6.1 Isolation Valves 5-8
5.6.2 Check Valves 5-8
5.6.3 Suction and Discharge Piping 5-9
5.6.4 Gauges and Meters 5-9
5.6.5 Water Seals 5-10
5.6.6 Surge Arrestor Systems 5-10

5.7 ELECTRICAL 5-10

5.7.1 Power Supply 5-10
5.7.2 Pump Motor 5-10
5.7.3 Stand-by Power 5-11
5.7.4 Controls 5-11

5.8 SAFETY PRECAUTIONS 5-12

5.9 STATION MONITORING 5-12

CHAPTER 6.0 TREATED WATER STORAGE FACILITIES 6-1

6.1 GENERAL 6-1

6.2 DEFINITIONS 6-1

6.2.1 Age of Treated Water 6-1
6.2.2 Detention Time 6-1
6.2.3 Elevated Tank 6-1
6.2.4 Standpipe 6-1

6.2.5 Reservoir 6-1
6.2.5.1 Above-Ground Reservoir 6-1
6.2.5.2 In-Ground Reservoir 6-2
6.2.6 Hydropneumatic Systems 6-3
6.3 MATERIALS OF CONSTRUCTION 6-4
6.3.1 Standards and Materials Selection 6-4
6.3.2 Steel Construction 6-4
6.3.3 Concrete Construction 6-4
6.4 DESIGN CRITERIA 6-4
6.4.1 Demand Equalization (Peak Balancing Storage) 6-5
6.4.2 System Operation (Convenience) 6-5
6.4.3 Smoothing Pumping Requirements 6-5
6.4.4 Reducing Power Costs 6-5
6.4.5 Emergency Storage 6-5
6.4.6 Fire Storage 6-5
6.4.7 Pressure Surge Relief 6-6
6.4.8 Detention Time 6-6
6.4.9 Blending of Water Sources 6-6
6.5 SIZING OF WATER STORAGE FACILITIES 6-6
6.5.1 Fire Flow Storage Requirements 6-8
6.5.2 Peak Balancing Storage Requirements 6-8
6.5.3 Emergency Storage 6-9
6.5.4 Dead Storage 6-9
6.5.5 Turnover and Water Quality 6-9
6.5.6 Plant Storage 6-9
6.5.6.1 Clearwell Storage 6-10
6.6 LOCATION OF DISTRIBUTION STORAGE 6-10
6.6.1 Elevated Storage 6-10
6.6.2 Above Ground and In-Ground Storage Reservoirs 6-10
6.7 FACILITY REQUIREMENTS 6-11
6.7.1 Inlet/Outlet and Baffle Wall 6-11
6.7.2 Level Control 6-11
6.7.3 Overflow 6-11
6.7.4 Drainage of Storage Structures 6-12
6.7.5 Roof Drainage 6-12
6.7.6 Roof and Sidewall 6-13
6.7.7 Vents 6-13
6.7.8 Frost Protection 6-14
6.7.9 Internal Catwalk 6-14

6.7.10 Silt Stop 6-14
6.7.11 Grading 6-14
6.7.12 Corrosion Prevention/Reduction 6-14
6.7.13 Disinfection 6-14
6.7.14 Provisions for Sampling 6-15
6.7.15 Adjacent Compartments 6-15
6.7.16 Basins and Wet-wells 6-15
6.7.17 Standby Power 6-15

6.8 WATER TREATMENT PLANT STORAGE 6-15

6.8.1 Backwash Tanks 6-15
6.8.2 Clearwell 6-15
6.8.3 Adjacent Compartments 6-16
6.8.4 Wet-Wells 6-16

6.9 HYDROPNEUMATIC TANKS 6-16

6.9.1 Location 6-17
6.9.2 Sizing 6-17
6.9.3 Piping 6-17
6.9.4 Appurtenances 6-17

6.10 SECURITY/SAFETY 6-17

6.10.1 Access 6-17
6.10.2 Safety 6-18
6.10.3 Protection 6-18

CHAPTER 7.0 TRANSMISSION AND DISTRIBUTION SYSTEMS 7-1

7.1 DEFINITIONS 7-1

7.1.1 Transmission Main 7-1
7.1.2 Primary Distribution Main 7-1
7.1.3 Distribution Main 7-1
7.1.4 Service Line (Lateral) 7-2
7.1.5 Service Connection 7-2
7.1.6 Water Demands 7-2

7.2 MATERIALS 7-3

7.2.1 Standards, Materials Selection 7-3
7.2.2 Used Materials 7-3
7.2.3 Joints 7-3
7.2.4 Corrosion Prevention/Reduction 7-4

7.3 DESIGN CRITERIA - TRANSMISSION AND DISTRIBUTION SYSTEMS 7-4

7.3.1 Transmission and Distribution Pipelines 7-4
7.3.1.1 Transmission Mains 7-4

7.3.1.2 Primary Distribution Mains 7-5
7.3.2 Water Demands 7-5
7.3.3 Pressure 7-6
7.3.4 Diameter 7-7
7.3.5 Velocity 7-7
7.3.6 Dead Ends / Looping Requirements 7-7
7.3.7 Fire Protection 7-7
7.3.8 Fire Pumps 7-8
7.3.9 Drain / Flushing Devices 7-8
7.3.10 Air Relief and Vacuum Valves 7-8
7.3.11 Flow Monitoring 7-9
7.3.12 Crossing Obstacles 7-9
7.3.12.1 Road Crossings 7-9
7.3.12.2 Sewers 7-9
7.3.12.3 Surface Water Crossings 7-9
7.3.12.4 Horizontal Drillings 7-10
7.3.13 Bedding 7-10
7.3.14 Cover 7-10
7.3.15 Thrust Restraint 7-10
7.3.16 Pressure and Leakage Testing 7-10
7.3.17 Disinfection 7-10
7.3.18 Commissioning 7-11

7.4 HYDRANTS 7-11

7.4.1 Location and Spacing 7-11
7.4.2 Valves and Nozzles 7-11
7.4.3 Hydrant Leads 7-11
7.4.4 Drainage 7-11

7.5 VALVE AND METERING CHAMBERS 7-12

7.5.1 Chamber Construction 7-12
7.5.2 Air Relief and Vacuum Valves Chambers 7-12
7.5.3 Flow Measurement and Meter Chamber 7-12
7.5.4 Pressure Reducing Valve Chambers 7-12
7.5.5 Chamber Drainage 7-13

7.6 SEPARATION DISTANCES TO SANITARY AND STORM SEWERS 7-13

7.6.1 Parallel Installation 7-13
7.6.2 Crossings 7-13
7.6.3 Forcemains 7-14
7.6.4 Manholes 7-14
7.6.5 Other Sources of Contamination 7-14
7.6.6 Exceptions 7-14

7.7 CROSS CONNECTION CONTROL 7-14
- 7.7.1 Cross Connection Control Programs 7-14
- 7.7.2 Interconnections 7-15
- 7.7.3 Back-Flow Prevention 7-15

7.8 WATER SERVICES AND PLUMBING 7-15
- 7.8.1 Plumbing 7-15
- 7.8.2 Consumer Connections (Laterals and Curb-Stops) 7-15
- 7.8.3 Booster Pumps 7-16
- 7.8.4 Service Meters 7-16
- 7.8.5 Water Loading Stations 7-16
- 7.8.6 Sampling Stations 7-16

CHAPTER 8.0 OPERATION AND MAINTENANCE 8-1

8.1 GENERAL 8-1

8.2 SURFACE WATER SOURCE FACILITIES 8-1
- 8.2.1 Water Quality Documentation 8-1
- 8.2.2 Operational Requirements 8-1
- 8.2.3 Maintenance Requirements 8-2
- 8.2.4 Documentation 8-2

8.3 GROUNDWATER SOURCE FACILITIES 8-2
- 8.3.1 Water Quality Documentation 8-2
- 8.3.2 Operational Requirements 8-2
- 8.3.3 Maintenance Requirements 8-3
- 8.3.4 Documentation 8-3

8.4 PUMPING FACILITIES 8-3
- 8.4.1 Operational Requirements 8-3
- 8.4.2 Maintenance Requirements 8-4

8.5 WATER TREATMENT FACILITIES 8-4
- 8.5.1 Water Quality Documentation 8-4
- 8.5.2 Operational Requirements 8-4
- 8.5.3 Maintenance Requirements 8-5
- 8.5.4 Documentation 8-6

8.6 TREATED WATER STORAGE FACILITIES 8-6
- 8.6.1 Operation and Maintenance Requirements 8-6
- 8.6.2 Cold Weather Operation 8-7

8.7 TRANSMISSION AND DISTRIBUTION SYSTEMS 8-7
- 8.7.1 Operation and Maintenance Requirements 8-7

8.9 SAFETY 8-8

8.10 OVERALL DOCUMENTATION 8-8

8.11 OPERATOR TRAINING SCHEDULING 8-9

8.12 SCADA MONITORING 8-9

8.13 SECURITY 8-9

CHAPTER 9.0 SMALL WATER SUPPLY SYSTEMS 9-1

9.1 GENERAL 9-1

9.2 OUTLINE OF A SMALL WATER SUPPLY SYSTEM 9-1

9.3 APPROVALS REQUIREMENTS 9-2

- **9.3.1 Pre-Consultation** 9-2
- **9.3.2 Pre-Design Report** 9-2
- **9.3.3 Review of Pre-Design Report** 9-3
- **9.3.4 Acceptance of Pre-Design Report** 9-3
- **9.3.5 Detailed Design Submission** 9-3
- **9.3.6 Review of Design Submission** 9-3
- **9.3.7 Issue of Approval/Permit to Construct** 9-4
- **9.3.8 Post Construction Report/Certificate of Compliance** 9-4
- **9.3.9 Issue of Approval/Permit to Operate** 9-5

9.4 WATER USE REQUIREMENTS 9-5

- **9.4.1 Average Use** 9-5
- **9.4.2 Maximum Day Demand** 9-6
- **9.4.3 Peak Hour Demand** 9-6
- **9.4.4 Outdoor Use** 9-7
- **9.4.5 Fire Protection** 9-7

9.5 SOURCE OF SUPPLY 9-7

- **9.5.1 Surface Water** 9-7
  - 9.5.1.1 Impounding Reservoirs 9-7
  - 9.5.1.2 Intakes 9-7
  - 9.5.1.3 Raw Water Pumps 9-8
- **9.5.2 Groundwater** 9-8
  - 9.5.2.1 Number of Wells 9-9

9.6 WATER TREATMENT 9-9

- **9.6.1 Treatment of Surface Water** 9-9
  - 9.6.1.1 Disinfection of Surface Water 9-10
- **9.6.2 Treatment of Groundwater** 9-10
  - 9.6.2.1 Disinfection of Groundwater 9-10

9.6.3 Methods of Disinfection 9-10

9.7 AUXILIARY POWER 9-11

9.8 WATER STORAGE 9-11

9.8.1 Storage Capacity 9-11
9.8.2 Water Storage Materials 9-11
9.8.3 Treated Water Pumps 9-12
9.8.4 Acceptable Pressure 9-12

9.9 PRESSURE TANKS 9-12

9.10 WATER DISTRIBUTION SYSTEM 9-12

9.10.1 Material 9-12
9.10.2 Distribution System Piping Diameter 9-12
9.10.3 Pressure Rating 9-12
9.10.4 Velocities 9-12
9.10.5 Service Connections 9-13
9.10.6 Water Meters 9-13
9.10.7 Hydrants 9-13
9.10.8 Individual Home Booster Pumps 9-13

9.11 MONITORING REQUIREMENTS 9-13

9.12 FACILITY CLASSIFICATION AND OPERATOR CERTIFICATION 9-13

9.13 EASEMENTS, STATUTORY RIGHTS OF WAY, AND RESTRICTIVE COVENANTS 9-14

APPENDICES

A References

Chapter 1.0 APPROVAL REQUIREMENTS AND PROCEDURES

1.1 GENERAL OVERVIEW OF APPROVALS

The regulatory authorities in Atlantic Canada require that an application for approval for the construction, modification, or operation of a water system be made in writing using the official application form for the Province in which the work is to be constructed. The application should be submitted to the regulator and should be signed by the owner, or where authorization is provided, a person representing the owner.

1.1.1 Summary of Approval Process

The approval process should generally be considered as a multiple step procedure. It is recommended that early and full consultation be maintained between all involved parties including the owner, design team, regulators, and other involved groups through regular consultation and status review meetings through the concept, design, approval, and construction stages.

The procedure is summarized and expanded upon in the following sections.

1. **Pre-consultation** with the regulator to establish if special requirements exist (Section 1.2.1);

2. **Preparation and submission of a Pre-design (Technical) report** to the regulator (Section 1.2.2);

3. **Review of Pre-design report** by the regulator (Section 1.2.3);

4. **Acceptance of Pre-Design report** from the regulator, indicating conditions of conceptual approval of the project (Section 1.2.4);

5. **Preparation and submission of detailed design plans, design brief, specifications, and other supporting documentation** as required by the regulator (Section 1.2.5);

6. **Review of Design submission** by the regulator (Section 1.2.6);

7. **Issue of a Permit/Approval to Construct** by the regulator (Section 1.2.7);

8. **Preparation and submission of documentation of construction compliance, inspection, administration and acceptance, as-built drawings, and post-construction report** (Section 1.2.8);

9. **Issue of Permit/Approval to Operate** by the regulator (Section 1.2.9).

Proponents planning a water supply project should consult with the regulator to discuss the scope of the project and to determine the level of engineering services that are required for approval.

The services outlined are generally performed by engineering firms in private practice but may be executed by municipal or provincial agencies with qualified in-house engineering services.

A pre-design report will generally be required to initiate projects involving the development/upgrade of the following:

- Water supply sources;
- Pump-house infrastructure;
- Water treatment systems;
- Transmission mains;
- Distribution system reservoirs, booster pumps, and pressure reducing valves.

Small extensions of a water distribution system within the boundaries of the service area may not require a pre-design report, provided that the scale of the extension is within the scope of the existing water distribution master plan.

Although not required under this document, all utilities are encouraged to develop a water distribution master plan. The water distribution master plan can be used to prevent uncontrolled extensions of the water distribution system.

The pre-design investigation may provide a "screening" opportunity to determine if the project requires an assessment and/or registration under the respective Environmental Assessment Act. The respective provincial regulators should be contacted to determine specific requirements.

The pre-design report should be submitted to the regulator, with a request for comments or "concept approval." **Acceptance of pre-design report from a regulator, however, should not be considered as having received official approval to proceed with construction or modification of a project.**

In addition to the pre-design report, a detailed financial feasibility analysis of the proposed project, including an analysis of required water rates, may be required in some jurisdictions. The requirements for a financial feasibility analysis are not included in this Manual.

A detailed design of the proposed water works, submitted with a formal application to the regulator, is required for the construction or modification of a water system. The application should include plans, specifications, a design brief, and any other information as required by the regulatory agency. The submission should make use of the data presented in the pre-design report, but should be a stand alone document that does not require the reviewer to refer to the pre-design report.

Where applicable, a processing fee form should be completed and the appropriate fee submitted.

The formal approval application, with the plans, specifications, and supporting documentation, should be submitted at least 90 days, or as specified by jurisdiction having authority, prior to the planned start of the construction or modification project. The plans, specifications and supporting documentation should be stamped with the seal and signature of a Professional Engineer that is licensed to practice in the Province of application. The application should be submitted to the regulatory agency and should be signed by the owner, or where authorization is provided, a person representing the owner.

The regulator should review the application to determine if it conforms with policies, standards or guidelines enforced by the department. During the review of the application, the regulator may request oral or additional written information on the project. If requested information is not received, the regulator may declare the application incomplete, and advise the applicant of such.

An “Approval/Permit to Construct” should be issued after the design application has been reviewed and found to be satisfactory. **The proposed works should not be undertaken by the proponent until the official "Permit/Approval to Construct” has been issued by the regulator.**

(The Province of Prince Edward Island provides one approval only: Part I, Construction Requirements, and Part II, Operations.)

A "Post-Construction Report/Certificate of Compliance" should be provided at the completion of the project. The report should contain all information regarding major changes from the approved plans or specification made during construction. Major changes include any deviations which affect capacity, flow, or operation of units. The report should also include results of all test runs of the water treatment plant to demonstrate that the plant can produce water meeting all applicable standards.

After the submission of the Post-Construction Report/Certificate of Compliance, the regulatory agency may provide an “Approval/Permit to Operate” if all aspects of the project are acceptable.

The purpose of the permit is to clearly outline the operating and reporting requirements for the water supply system.

The expiry date of the approval/permit and the terms for renewal should be indicated by the regulator.

1.1.2 Review by Other Jurisdictions

Projects may require a review and approval from other Federal and Provincial government jurisdictions to address specific issues related to the proposed project.

1.2 OUTLINE OF APPROVAL PROCESS

1.2.1 Pre-Consultation

Proponents planning a water supply project should consult with the regulator to discuss the scope of the project and to determine the regulatory requirements.

1.2.2 Pre-Design (Technical) Report

1.2.2.1 Purpose of a Pre-Design Report

A pre-design report should be considered as good engineering practice even when not required by a regulatory agency.

A pre-design evaluation will generally be required by the regulator for large scale projects and/or projects involving the development or upgrade of the following:

- Water supply sources;
- Pump-house infrastructure;
- Water treatment systems;
- Transmission mains;
- Distribution system reservoirs, booster pumps, and pressure reducing valves.

The pre-design report should document the "problem statement" or the "problem to be solved", which may or may not be the same as the long-term goals.

The purpose of a pre-design report is to assess the existing infrastructure and operating conditions, and to determine the alternatives in sufficient detail to permit the following:

- Provide an overview of the existing infrastructure;

- Indicate the limitations of the existing infrastructure;
- Indicate existing water quality compared to existing provincial and industry standards;
- Present reliable water use projections;
- Identify the long term goals of the work being considered;
- Assess alternate options of resolving the limitations in an effort to meet the long term goals which have been identified;
- Identify geo-technical issues;
- Identify capability to produce drinking water to meet provincial and industry standards;
- Identify treatment process options which were evaluated;
- Provide estimated construction and operational costs;
- Provide a recommendation regarding feasible options;
- Provide a concept plan of the recommended option; and
- Outline requirements for project implementation and approval by regulatory agencies.

Architectural, structural, mechanical and electrical conceptual designs are typically not included in the pre-design evaluation, however, their estimated costs must be evaluated in terms of their impact on the overall project costs. Sketches may be included to describe treatment processes where applicable. Outline specifications of process units and special equipment may also be included.

A pre-design evaluation for a proposed project is typically used by:

1. The municipality, utility, private developers or industry, for a project description, including findings, conclusions, cost estimates, financing requirements and recommendations;

2. Designers to establish the overall scope of design and for the arrangement, capacity, and type of components to be designed;

3. The regulator for evaluation of environmental impacts, for examination of process operations, for verifying compliance with Water Treatment Standards, and for the issuance of a "Concept Approval" prior to the initiation of detailed design;

4. Investment groups and government funding agencies to evaluate the "quality" of the proposed project with reference to authorization and financing; and

5. News media for description of the project;

The pre-design report should be complete so that plans and specifications may be developed from the pre-design without substantial alteration of concept and basic considerations. In short, basic thinking, fundamentals and decisions are outlined in the pre-design report and carried out in the detailed design plans and specifications.

A pre-design report will be considered valid for a period of 5 years unless new information has resulted in it being obsolete.

1.2.2.2 Contents of a Pre-Design Report

The pre-design evaluation should, where applicable, include but not be limited to consideration of the following:

- Identification of utility or private developers (name, address, telephone);
- Determination of service area;
- Determination of equivalent service population;
- Summary of water consumption data;
- Future population and water consumption projections;
- Description of surface water supply source:
    - Sites considered and reasons for selection;
    - Location and physical setting of watershed;
    - Watershed ownership and management issues;
    - Watershed area;
    - Safe yield (winter and summer);
    - Existing and potential sources of contamination;
    - Raw water quality;
    - Proposed intake location (vertical and horizontal);
    - Impound requirements;
    - Flow maintenance requirements;
    - Other water use and withdrawal rates;
    - Intake location; and
    - Intake security.

- Description of Groundwater Supply Source:
    - Sources of data;
    - Sites considered and reasons for selection;
    - Location and physical setting of aquifer;
    - Land Ownership and land use;
    - Aquifer protection and management issues;
    - Availability of water (peak versus safe use, plus competing

  uses in areas); and
  - Summary of source exploration (test well depths, location, pumping data).

- Description of Hydrogeology:
  - Topography and drainage;
  - Location of existing water supplies;
  - Raw water quality;
  - Existing and potential sources of contamination, including historical site data such as abandoned dumps, industrial sites, etc.;
  - Surficial geology;
  - Bedrock geology;
  - Descriptions of pumping and observation wells;
  - Aquifer hydraulic properties;
  - Safe well yields;
  - Safe aquifer yield;
  - Well head completion details;
  - Water levels; and
  - History of well maintenance and monitoring.

- Water Treatability:
  - Fluctuations in raw water quality;
  - Water quality parameters that exceed limits;
  - Trihalomethane (THM) formation potential;
  - Treatment requirements;
  - Bench-scale tests;
  - Pilot scale tests;
  - Treated water quality; and
  - Impacts on the water distribution system.

- Raw water storage reservoir:
  - Natural storage; and
  - Engineered storage.

- Raw water transmission main:
  - Pumping/pressure reduction requirements;
  - Capacity of main;
  - Pipe material;
  - Routing considerations;

    - Soil conditions;
    - Groundwater elevation; and
    - Contaminated sites.

- Water treatment facility:
    - Plant sizing;
    - Design life;
    - Basic treatment concept:
        - Number of process trains;
        - Custom made or package plant.
    - Treatment processes;
    - Capacity of treatment units;
    - Hydraulic gradeline through plant;
    - Method of solids removal:
        - Sedimentation;
        - Dissolved air flotation.
    - Filter system type (slow, rapid; pressure, membrane);
    - Filtration area and rates;
    - Filter media type;
    - Filter redundancy;
    - Backwash type (air, scour);
    - Backwash rates;
    - Process waste disposal;
    - Sanitary wastewater disposal;
    - Disinfection process;
    - Disinfection equipment, housing, and redundancy;
    - CT factor;
    - Chemicals used;
    - Chemical feeder capacity and ranges;
    - Chemical containment and storage;
    - Corrosion control;
    - Water quality monitoring;
    - Storage requirements;
    - Integration of new facilities in existing system;
    - Future expansion / modifications possibilities;
    - Security;
    - Automation and instrumentation;
    - Process control and compliance monitoring;
    - High lift pumping / pressure reduction;
    - Emergency Power;

  - Personnel space requirements (i.e., lab and maintenance);
  - Solid waste management; and
  - Facility classification.

- Treated water quality:
  - Monitoring;
  - Health related parameters;
  - Aesthetic related parameters;

- Treated water transmission main:
  - Redundancy (single or twinned);
  - High lift pumping;
  - Hydraulic Analysis.
    - Ultimate production capacity of treatment plant;
    - Existing capacity and available storage;
    - Future connection requirements;
    - Pressure reduction;
    - Air release;
    - Line valves;
    - Surge analysis;
    - Maximum and minimum operating pressures;
    - Residential fire flow requirements;
    - Residential/industrial/commercial fire Flow requirements;
    - Minimum fire flow residual pressures;
    - Maximum pipe line velocity;
    - Maximum day demand factors;
    - Water quality monitoring stations;
    - Drainage procedures (including dechlorination, when required);
    - Route Location;
    - Topographic survey;
    - Land and easement acquisitions;
    - Existing services (power, sanitary, stormwater, communication cables, gas);
    - Geo-technical survey requirements;
    - In-ground control chambers;
    - Above ground control chambers;
    - In-ground meter chambers;
    - Above ground meter chambers.

    - Other considerations:
        - Erosion and sedimentation measures;
        - Traffic control;
        - unsuitable material in excavation;
        - Soil corrosiveness;
        - Contaminated soils;
        - Groundwater elevation;
        - Depth of frost.
    - Acceptable pipe material (AWWA Standards for pipe material based on pressure and geotechnical conditions).

- Treated water storage:
    - Siting/Location;
    - Sizing;
    - Top water elevation;
    - Lowest operating water level;
    - Baffling/water circulation (water quality issues);
    - Elevated storage;
    - Ground level storage;
    - Rechlorination requirements;
    - Monitoring;
    - Security issues:
        - Contamination;
        - Potential for vandalism.

- Water distribution system:
    - Extent of the distribution system;
    - General distribution system data:
        - Pipe material;
        - Pipe age;
        - Pipe diameter;
        - Maximum velocity;
        - Groundwater elevation;
        - Separation from sewers;
        - Valve placement;
        - Hydrant requirements;
        - Water service lateral material;
        - Pressure zones and related valves or pumps;
        - Hydraulic gradeline analysis;
        - Surge analysis;

    - Water loss considerations;
    - Cross connection control program; and
    - Stream crossings.
  - Age related water quality issues:
    - Dead end mains;
    - Chlorine residual concerns;
    - THM concerns;
    - Nitrification concerns;
    - Biofilm growth and bacterial regrowth; and
    - Impact of treatment process on distribution system.
  - Adequacy of fire fighting capacity;
  - Watermain upgrade/replacement requirements;
  - Domestic water only versus fire flow; and
  - Cross connection control program requirements.

- Maintenance and operation requirements;

- Evaluation of options;

- Preliminary cost estimates of options;

- Concept plan of recommended options; and

- Any other requirements of the regulator.

1.2.2.3 Key Components of a Pre-Design Evaluation

The following are considered to include key components of a pre-design evaluation.

1.2.2.3.1 Future Population and Commercial/Industrial Uses

The construction of a new water system or the extension of an existing system will require an estimate of the future population within the service area. Appropriate planning personnel should be consulted as part of this exercise, and particular attention is required to zoning designations in an effort to determine where commercial and / or industrial uses may be developed in the future.

1.2.2.3.2 Water Demand Projections

Population trends, development trends, serviceable boundaries, and the potential for commercial and/or industrial zoning should be used to project future average and maximum daily demands, including fire flows where applicable, for a 20 year period. Projections should be realistic, and may incorporate a plan for expanding the facility.

Water loss should be considered, and where appropriate, efforts should be made to establish a program to reduce water loss.

1.2.2.3.3 Design Criteria

The quantity of water at the source shall be adequate to meet the maximum projected water demand of the service area as shown by calculations based on extreme drought of record while not significantly affecting the ecology of the water course downstream of the intake.

The water transmission, distribution and storage infrastructure should be designed to provide the required flows and pressures for the range of demand expected.

The design criteria used in the evaluation of the options should be outlined in the pre-design report.

1.2.2.3.4 Site Selection of Treatment Facility

Site selection of a large water supply component such as a water treatment plant or a reservoir will require consideration of a variety of factors including:

- Water quality if more than one source is available;
- Location of source of supply;
- Land ownership issues;
- Security issues;
- Proximity to developed areas;
- Hydraulic integration of the new facility into the existing system;
- Proximity to sensitive areas;
- Flood concerns;
- Fire hazard concerns;
- Geo-technical considerations;
- Transmission and distribution system upgrade requirements;
- Energy requirements;
- Available disinfectant contact time to first customer;
- Proximity to sanitary sewer;
- Proximity to power services;
- Access road requirements;
- Site topography and drainage; and
- Site maintenance.

1.2.2.3.5 Conceptual Layout of Treatment Plant

The selection of a preferred site, the selection of a water treatment process train and ancillary equipment, and the assessment of the hydraulic impact on the transmission and distribution system, will allow for development of the conceptual layout of the required water treatment plant.

The concept layout of the treatment plant should include, where applicable, consideration of the following:

- Functional aspects of the plant layout:
  - Number of process trains.
- Provisions for future plant expansion;
- Provisions for expansion of the plant waste treatment and disposal facilities (if on-site);
- Access road;
- Site grading and drainage;
- Driveways and parking areas;
- Chemical delivery access;
- Chemical storage and feed equipment requirements;
- Provision for power;
- Provisions for stand-by power;
- Adequate shop space and storage;
- Laboratory Facilities; and
- Facility sanitary wastewater disposal requirements.

1.2.2.3.6 Ancillary Equipment and Infrastructure

In addition to the major treatment process units, the development of a water treatment plant will require consideration of ancillary process such as:

- Type of disinfectant;
- Requirements for alternative disinfectant;
- Types of chemicals required;
- Corrosion control requirements;
- Fluoridation; and
- Waste treatment.

1.2.2.3.7 Route Selection of Transmission Mains

The evaluation of a route of a transmission main should include land and easement acquisition requirements. Where options are evaluated, future connections and existing services should be identified.

1.2.2.3.8 Site Selection of Water Storage Reservoirs

The top water level and the location of a water storage reservoir floating on the distribution system should be selected to result in acceptable service pressure throughout the distribution system under all demand conditions. Acceptable pressures are discussed in Chapter 7 - Transmission and Distribution Systems.

1.2.2.3.9 Cost Estimates and Financing

The concept development of major infrastructure should allow for a class C cost estimate of the project to be carried out.

A Class C estimate is based upon concept plans and an outline of design systems of the intended project. This concept represents one solution of the design problem but not necessarily the eventual solution to the design problem. This estimate is based on completion of all work necessary to begin the preliminary design.

The Class C estimate must be based on knowledge of site conditions adequate to enable the identification of site related risks and the development of corresponding contingency costs that are sufficient to making the correct investment decision.

The Class C estimate is more detailed than a Class D estimate (which would be an order of magnitude estimate based simply on a statement of requirements) and less accurate than a Class B estimate (which would be based on the completed preliminary design drawings).

In addition, where alternate treatment processes are being evaluated, a net-present-worth analysis, or life cycle costing, should be carried out on the applicable processes, using a minimum 20 year period, to select the most cost effective option for the utility. Both capital and operating costs should be taken into consideration when conducting the evaluation.

Estimates of capital costs should include a breakdown by the 16 Divisions of the National Master Specification of all proposed capital works, as well as specific allowances for

- Engineering services;
- Pilot testing;
- Contingencies; and
- Costs of additional evaluations.

The 16 Divisions of the National Master Specification are as follows:

- 01 General Siteworks;
- 02 Sitework;
- 03 Concrete;
- 04 Masonry;
- 05 Metals;
- 06 Woods and Plastics;
- 07 Thermal and Moisture Protection;

- 08 Doors and Windows;
- 09 Finishes;
- 10 Specialties;
- 11 Equipment;
- 12 Furnishings;
- 13 Special Construction;
- 14 Conveying Systems;
- 15 Mechanical; and
- 16 Electrical.

Estimates of annual operating costs should include the following:

- Chemicals;
- Heat and power;
- Maintenance;
- Labour;
- Security;
- Monitoring and testing;
- Source water protection;
- Other utilities (i.e., phone, internet); and
- Ongoing training costs.

1.2.3 Review of Pre-Design Report

The pre-design report will be reviewed by the utility and the regulator. Allow 60 days for review by the regulatory agency.

1.2.4 Acceptance of Pre-Design Report

The regulatory agency should indicate acceptance of the Pre-Design report, and generally indicate whether there are any significant impediment to moving ahead with the detailed design and implementation of the proposed works. Acceptance of the pre-design report should not be viewed as an approval to construct the proposed works.

1.2.5 Detailed Design Submission

1.2.5.1 General

The owner or authorized representative must prepare and submit an application and detailed design documents to the regulator for approval. The application should be signed by the owner, or where authorization is provided, a person representing the owner.

Applications for specific items within the project, such as stream crossings and withdrawal permits, may require approval from other jurisdictions.

An Approval/Permit to Construct cannot be issued until final, complete, detailed plans and specifications have been submitted to the regulator, reviewed, and found to be satisfactory.

Detailed design documentation to be submitted with the application should include, but not be limited to:

- Design brief;
- Design plans;
- Specifications;
- Quantities and cost estimates; and
- Other information as required by the regulator.

1.2.5.2 Plans

All plans for water works should bear a suitable title showing the name of the owner, the location of the project, the project name, and should show the scale in appropriate units, the north point, date and the name of the engineer, their signature on an imprint of their registration seal.

The plans should be clear and legible. They should be drawn to scale which will permit all necessary information to be plainly shown. Datum used should be indicated. Locations and logs of test borings, when made, should be shown on the plans.

Detail plans should consist of plan views, elevations, sections and supplementary views that, together with the specifications and general layouts, provide the working information for the contract and construction of the works. Components should include if applicable, but not be limited to:

1. Site and key plan;

2. Streets to be serviced;

3. Areas where the new system will connect to the existing system, and connection details;

4. Stream crossings, providing profiles with elevations of the stream bed and the normal and extreme high and low water levels;

5. Details of underwater crossings, and methods used to prevent pipe breakage and discharge of chlorinated water into the watercourse, in aerial or underwater crossings;

6. Profiles having clearly indicated and appropriate horizontal and vertical scales;

7. Location and size of the property to be used for the source water development with respect to known references such as roads, streams, section lines, or streets;

8. Topography and arrangement of present or planned wells or structures, with appropriate contour intervals;

9. Elevations of the highest known flood level, floor of the structure, upper terminal of protective casings and outside surrounding grade, Geodetic elevations, reference;

10. Plan and profile drawings of well construction, showing diameter and depth of drill holes, casing and liner diameters and depths, grouting depths, elevations and designation of geological formations, water levels and other details to describe the proposed well completely;

11. Location of all existing and potential sources of pollution which may affect the water source or underground treated water storage facilities, including historical land uses to account for abandoned landfills or industrial sites;

12. Size, length, and identity of sewers, drains, and watermains, and their locations relative to facility structures;

13. Schematic flow diagrams and hydraulic profiles showing the flow through various facility units;

14. Piping in sufficient detail to show flow through the facility, including waste lines and floor drains;

15. Locations of all chemical storage areas, feeding equipment, points of chemical application, and spill containment details;

16. All appurtenances, specific structures, equipment, water treatment plant waste disposal units and points of discharge having any relationship to the plans for watermains and/or water works structures;

17. Locations of sanitary or other facilities, such as lavatories, showers, toilets, and lockers;

18. Locations, dimensions, and elevations of all proposed plant facilities;

19. Locations of all sampling taps, draw-off points, and on-line monitoring;

20. Adequate description of any features not otherwise covered by the specifications;
21. Architectural drawings;
22. Mechanical drawings;
23. Electrical drawings;
24. P & ID drawings; and
25. Miscellaneous details.

1.2.5.3 Technical Specifications

Complete technical specifications for the construction of impoundment structures, intakes, pumping stations, wells, water treatment plants, transmission mains, reservoirs, distribution system piping, valve chambers, and all appurtenances, should accompany the plans.

The specifications accompanying construction drawings should include, but not be limited to the following:

- All construction information not shown on the drawings which is necessary to inform the builder in detail of the design requirements as to the quality of materials and workmanship and fabrication of the project and the type, size, strength;
- Operating characteristics and rating of equipment;
- The complete requirements for infrastructure equipment, including machinery, valves, piping and jointing of pipe; electrical apparatus, wiring and appurtenances;
- Instructions for testing materials and equipment as necessary to meet design standards; and
- Operating tests for the completed works and component units. (It is suggested that these performance tests be conducted at design load conditions wherever practical).

1.2.5.4 Design Brief

The Design Brief should contain all the up-to-date technical information on the project. It should make use of the data presented in the pre-design report, but should be a stand alone document that does not require the regulator to refer to the pre-design report.

The design brief should present, where applicable, the following information:

1.2.5.4.1 General Information

General information on:

- Existing water works infrastructure;
- Identification of area serviced; and
- Name of owner / utility (contact person, address, telephone).

1.2.5.4.2 Extent of Water Works System

The extent of the water works system should include:

- Extent of area to be serviced; and
- Provisions for future extensions.

1.2.5.4.3 Soil, Groundwater Conditions, and Foundation Problems

Soil, groundwater conditions, and foundation problems, including a description of:

- The character of the soil through which watermains are to be laid;
- Foundation conditions prevailing at sites of proposed structures;
- The approximate elevation of groundwater in relation to subsurface structures; and
- De-watering provisions if necessary.

1.2.5.4.4 Water Demands

1. A description of the population trends as indicated by available records, and the estimated population which will be served by the proposed water supply system or expanded system.

2. Present water consumption and the projected average and maximum daily demands.

3. Status of fire flow demand and fire flow storage.

4. Present and/or estimated yield of the sources of supply; and

5. Unusual occurrences and/or major commercial or industrial demands

1.2.5.4.5 Hydraulic Evaluations of Transmission and Distribution Systems

1. Hydraulic analyses based on flow demands and pressure requirements;

2. Fire flows, when fire protection is provided, meeting the recommendations of the Insurance Advisory Organization (IAO) or other similar agency for the service area involved.

1.2.5.4.6 Sources of Water Supply

Describe the proposed source of water supply to be developed, the reasons for the selection, and provide information as follows:

For surface water sources, include, but not be limited to:

- Area of watershed;
- Source surface area and volume;
- Safe and maximum yield;
- Other users of the source;
- Factors that may affect the source;
- Maximum flood level, together with approval for safety features of the spillway and dam from the appropriate reviewing authority;
- Description of the watershed, noting any existing or potential sources of contamination (such as highways, railroads, chemical facilities, agricultural uses) that may affect water quality;
- Summarized quality of the raw water with special reference to fluctuations in quality, changing meteorological conditions, etc.;
- Source water protection issues or measures that need to be considered or implemented;
- Fish maintenance requirements;
- Ice conditions; and
- Evidence that applicant has approval to withdraw water.

For Groundwater sources, include, but not be limited to:

- Safe and maximum yield for each production well and for the entire wellfield;
- Elevation of wells with respect to surroundings;
- Probable hydrogeologic character of formations through which the source is to be developed;
- Hydrogeologic conditions affecting the site, such as anticipated interference between proposed and existing wells;
- Estimate capture area and pumping radius of influence for production wells;
- Summarized quality of the raw water with special reference to fluctuations in quality, changing meteorological conditions, etc.;
- Summary of source exploration, test well depth, and method of construction, placement of liners or screen, test pumping rates and their duration, water levels, and specific yield;
- Sources of possible contamination;
- Well head completion method (vault, pitless adaptor);
- Wellhead protection measures being considered; and
- Evidence that applicant has approval to withdraw water.

1.2.5.4.7 Design Criteria for Water Treatment Plants

The design brief for a water treatment plant should confirm that the design criteria used conforms to the requirements of the regulator. It is recommended that the design criteria include, but not be limited to, the following:

- Intake size, type and location;

- Intake velocity;
- Screening type and location;
- Coagulation/Flocculation process;
- Solids separation process;
- Surface and/or solids loading rates;
- Chemical feed systems and feed rates;
- Filter system type (slow, rapid, pressure, membrane);
- Filter media specifications;
- Number of filters;
- Filtration area and rate;
- Number of treatment trains;
- Process specific parameters (TOC, colour, turbidity);
- Disinfection process;
- Disinfection equipment redundancy;
- Disinfection by-products formation potential;
- CT values and details;
- Storage allowance or requirements; and
- Backwash requirements:
    - Proposed disposal method;
    - Location;
    - Chemical, physical and biological characteristics;
    - Volume;
    - Applicable discharge regulations;
    - Aluminum background in receiving water;
    - Final disposal; and
    - Possible impact on receiving waters.

1.2.5.4.8 Automation

Provide a list of instrumentation and automated systems, as well as supporting data outlining automatic equipment, and the overall operations strategy for the facility. Note that manual override and alarms must be provided for any automatic controls.

1.2.5.4.9 Requirements for Operation During Construction

Where applicable, the submission should contain a program for keeping the existing water works facilities in operation during construction of additional facilities so as to minimize interruption of service.

If applicable consideration should be given to increased water quality monitoring (process and compliance) and to increased staff requirements during construction. Should it be necessary to take facilities out of operation, a shut-down schedule that will maintain a safe supply of water to the users should be prepared and submitted for approval to the regulator.

1.2.6 Review of Design Submission

Copies of the application and all supporting documentation should be submitted to the regulator.

The application should refer to the pre-design report if applicable, and should include plans, specifications, a design brief, and any other information as required by the regulator.

Where applicable, a processing fee form should be completed and the appropriate fee submitted.

The formal approval application, with the plans, specifications, and supporting documentation, should be submitted at least 90 days prior to the planned start of the construction or modification project. The plans, specifications and supporting documentation should be stamped with the seal and signature of a Professional Engineer that is licensed to practice in the Province of application. The application should be submitted to the regulator and should be signed by the owner, or where authorization is provided, a person representing the owner.

The regulator should review the application to determine if it conforms with policies, standards, regulations, or guidelines enforced by the agency. During the review of the application, the regulatory agency may request oral or additional written information on the project. If requested information is not received, the regulator may declare the application incomplete, and advise the applicant of such.

1.2.7 Issue of Approval/ Permit to Construct

An "Approval/Permit to Construct" should be issued by the regulator after the design application has been reviewed and found to be satisfactory. **The proposed works should not be undertaken by the proponent until the official "Permit/Approval to Construct" has been issued.**

The Approval/Permit will provide the owner with the authority to proceed with a public tendering and construction of that particular project.

Any changes in the approved works, or works other than those specified in the application, must be submitted in writing to the regulator, and approved, in the form of an amendment to the approval/permit prior to construction.

(The Province of Prince Edward Island provides one approval only: Part I, Construction Requirements, and Part Ii, Operations.)

1.2.8 Post Construction Report/Certificate of Compliance

A "Post-Construction Report/Certificate of Compliance" should be provided at the completion of the project. The report should contain all information regarding major changes from the approved plans or specification made during construction. These major changes include any deviations, which affect capacity, flow or operation of units.

Information required includes, but is not limited to, the following:

- Equipment start-up tests and any other tests results produced during construction;
- Results of start-up of the plant confirming that treated water meets the water quality requirements;
- Confirmation that the plant and its' components, watermains, and reservoirs have been properly disinfected prior to being placed in use;
- Confirmation that a cross-connection survey has been performed and cross connections have not been found;
- Confirmation that all components and chemicals are NSF compliant;
- Indication that as-built drawings, operation and maintenance manuals, and any other relevant documentation have been provided to the owner/operator and/or other body if required by the regulatory agency; and
- Confirmation that operator certification is consistent with provincial requirements.

In the event that specific information cannot be confirmed when the report is proposed, a plan outlining the time frame to comply should be submitted.

1.2.9 Issue of Approval/Permit to Operate

When applicable, the regulator should provide an "Approval/Permit to Operate".

The purpose of the permit is to clearly outline the operating and reporting requirements for the water supply system.

The expiry date of the approval/permit and the terms for renewal should be indicated by the regulatory agency.

(The province of Prince Edward Island provides one approval only: Part I, Construction Requirements, and Part II, Operations.)

1.3 MONITORING AND RECORDING REQUIREMENTS

Monitoring and recording requirements, where the responsibility of the utility, should be outlined by the regulator in the Approval/Permit to Operate.

The monitoring program should be carried out in compliance with sampling and analysis requirements outlined in the "Approval/Permit to Operate".
(The Province of Prince Edward Island provides one approval only: Part I, Construction Requirements, Part II, Operations.)

Monitoring by a regulator does not relieve the system owner of their responsibility related to this function. The system owner and operator maintain responsibility for all aspects of the system.

1.4 REPORTING REQUIREMENTS

Reporting should be carried out in compliance with the requirements outlined in the Approval / Permit to operate. In instances where monitoring is the responsibility of a regulator, reporting will be the responsibility of the regulator and/or laboratory.

1.5 FACILITY CLASSIFICATION AND OPERATOR CERTIFICATION

Some jurisdictions have adopted regulations that makes facility classification and operator certification mandatory, while others strongly recommend operator certification. Where applicable, the regulations require all water treatment and water distribution personnel to be certified, and require that an operator with a certification level equivalent or greater to the facility classification be in direct responsible charge.

The regulator should be consulted regarding specific requirements.

1.6 OWNER RESPONSIBILITY

The owner of any water treatment or water distribution system should practice due diligence, and should ensure that all monitoring and reporting is conducted in accordance with the requirements of the "Approval/Permit to Operate".

The owner should ensure that the operators are trained to operate the system. The owner should ensure that the operator has attained the required certification status and is provided with ongoing education and training.

1.7 REGULATOR RESPONSIBILITY

The responsibilities of the regulator should be as outlined in the latest respective provincial acts and other applicable regulations, policies, guidelines, and directives.

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Chapter 2.0 SOURCE WATER DEVELOPMENT

2.1 GENERAL

In selecting the source of water to be developed, the design engineer should prove to the satisfaction of the utility and the regulator that an adequate supply of water is available. In addition, it should be demonstrated that the water source to be developed is the most feasible source and meets, or the proposed level of treatment meets, the appropriate water quality standards.

A *surface water supply source* includes all tributary streams and drainage basins, natural lakes and artificial reservoirs or impoundments above the point of water supply intake.

A *groundwater supply* includes all water obtained from dug, drilled, bored or driven wells.

Groundwater under the direct influence of surface water (GUDI) is water beneath the surface of the ground with: 1) significant occurrence of insects or other macro-organisms, algae or large diameter pathogens such as Giardia lamblia, or 2) significant and relatively rapid shifts in water characteristics such as turbidity, temperature, conductivity or pH that closely correlate to climatological or surface water conditions.

Criteria used for determination of GUDI differs between jurisdiction, and the appropriate regulatory agency should be consulted.

Where alternate sources of water are available, the source with the highest quality water should be used if cost effective. (AWWA Policy).

2.2 SURFACE WATER

2.2.1 Quantity Assessment

A surface water quantity assessment should include a review of the available yield of the water supply.

Yield assessments can be estimated using different methods. Mass Flow curves can be generated from streamflow records. Alternatively, a record can be simulated using long-term precipitation data. Where data exists, both methods should be used and a comparison made between them.

Yield assessments should consider the following criteria:

1. Where streamflow data exists, mass flow curves should be used to estimate the minimum perennial yield on record and a drought return period should be determined for that year;

2. A minimum drought return period of one in fifty years (i.e., 1/50-yr) should be used for calculating safe yield;

3. A statistical analysis should be performed to determine the 1/20-yr return periods within a 95% confidence interval;

4. A minimum drought duration of 60 days should be used;

5. Where precipitation data is used to calculate yield, the runoff characteristics should adequately reflect the average conditions of the watershed;

6. All available storage should be considered in all yield calculations;

7. The yield should be adequate to meet the maximum and future water demand based on extreme drought of record, while not significantly affecting the ecology of the water course downstream of the intake;

8. The yield should be adequate to compensate for all losses such as silting, evaporation, and seepage; and

9. The yield should be adequate to provide ample water for other legal users of the source.

2.2.2 Watershed Delineation and Protection

2.2.2.1 Watershed Delineation

All surface water supplies should have their watersheds geographically delineated. Features that should be indicated include the following:

1. Watershed area;

2. Water surface area;

3. Municipal, provincial, federal and private ownership allocations, (if applicable);

4. Roads and highways;

5. Dwellings; and

6. Current and past land usage.

2.2.2.2 Watershed Protection

The owner of the surface water supply should have adequate watershed protection in place. This may include, but not limited to, the following measures:

1. Source Area Advisory Committee;

2. Source Area Protection Plans; and

3. Contingency Plans.

The respective provinces should be contacted for specific watershed protection regulations and requirements.

2.2.3 Water Treatment

All drinking water should meet drinking water standards and the Guidelines for Canadian Drinking Water Quality for the parameters identified by respective provincial regulators.

Surface water and GUDI, where applicable, will require treatment to meet drinking water standards and guidelines. The pre-design investigation should evaluate the treatability of the water using one or both of laboratory scale tests and pilot scale tests.

2.2.3.1 Laboratory Scale Testing Program

As a minimum, a pre-design investigation of an existing or new water supply should include a water quality sampling and treatability testing program in an effort to determine the relative performance of potential processes.

Large volume (50 L) samples should be collected from the source. Lab treatability tests conducted to establish the chemical, physical and biological requirements to produce treated water that meets provincial, federal and or industry drinking water guidelines or standards. The findings of the laboratory treatability tests program can be used to estimate appropriate design parameters of the process equipment, to assist in the concept design of the water treatment facility, and in the determination of a budget cost for the facility.

2.2.3.2 Pilot Scale Testing Program

A pilot scale treatment program should be conducted where laboratory testing results indicate that several process options are available for the treatment of the water, or where good background performance data does not exist for a specific process train which appears acceptable in a particular water supply.

The pilot scale testing results should be used to confirm that the process is capable of treating the water, and that the operational requirements and costs are acceptable. Piloting should be conducted over a sufficient period of time to enable all seasonal raw water quality fluctuations to be experienced, or to enable an acceptable degree of confidence that the process is capable of dealing with the fluctuations in water quality that are anticipated.

Information regarding, but not necessarily limited to, the following should be collected during the course of a pilot study:

1. Average, maximum and peak design flow rates;

2. Influent and pilot plant effluent quality including colour, turbidity, temperature, pH, iron, manganese, natural organic matter, chlorine demand, trihalomethane formation potential, microbiological characteristics, and any other such site-specific water quality data that may be deemed pertinent to the study (e.g., particle counts for membrane pilot studies or other parameters of concern identified in previous treatment studies);

3. Chemical requirements:
   a) Chemical types;
   b) Dosages; and
   c) Costs.

4. Flocculation requirements:
   a) Mixing intensity; and
   b) Flocculation time.

5. Clarification requirements:
   a) Retention times;
   b) Surface overflow rate;
   c) Plate/tube design criteria;
   d) Weir loading rates;
   e) Recycle rates, air concentrations and bubble diameters (if applicable); and
   f) Sludge flows and concentrations.

6. Filtration requirements:

   a) Filtration rates and/or flux rates;
   b) Headloss development and filter run times;
   c) Media types and specifications;
   d) Membrane materials (if applicable);
   e) Backwash and requirements including air scour, flow rate and backwash water quality;
   f) Reject characteristics including flow rates and quality (if applicable); and
   g) Scraping frequency and filter ripening periods (i.e., slow sand filtration).

7. Disinfection systems:
   a) Chlorine demand;
   b) Contact times;
   c) Residuals;
   d) Disinfection by-product formation potential;
   e) Intensity (UV systems only); and
   f) Inactivation.

8. Aeration systems:
   a) Air loading and/or flow rates;
   b) Mixing requirements;
   c) Pressure requirements; and
   d) Removal efficiencies.

9. Residuals handling and treatment:
   a) Characterization of residual streams including sources, flows, solids content as well as chemical, physical and microbiological quality;
   b) Treatment requirements including equalization, chemical addition, effluent quality and clarification requirements; and
   c) Recycling feasibility.

2.2.4 Required Intake Facility

The minimum required intake facility for a surface water supply includes, but is not limited to, the following:

1. A reservoir or impoundment that provides a water supply of adequate quantity and quality;

2. An intake structure with a screen that meets Department of Fisheries and Ocean (DFO) intake velocity requirements;

3. An intake that is set at optimum depth to draw water of highest quality;

4. A method by which to clean the screen and/or the intake; and
5. Located sufficient distance from shore to avoid shore wash influence.

2.2.5 Impoundments and Reservoirs

Impoundments and reservoirs should meet the following general requirements:

1. Should be of sufficient volume to sustain, if possible the 1/50-yr yield without significant drawdown (the volume should be confirmed by bathymetric survey at least once in 20 years);

2. Should have fish ladders or fish passages where stipulated by the authority having jurisdiction;

3. The hydraulic structure should be designed in accordance with the latest version of the Canadian Dam Safety Association: Dam Safety Guidelines, or the authority having jurisdiction; and

4. The site should be made as secure as is reasonably possible through the use of fencing, signage and patrolling/policing, if necessary.

2.3 GROUNDWATER SUPPLY

A minimum of two (2) wells should be provided. The well supply system should be designed to enable the system to operate with one well out of service provided that provincial health related water quality requirements are met while one well is out of service.

2.3.1 Location

Various factors influence the proper location of municipal supply wells, including: aquifer hydraulic properties and distribution, expected groundwater flow directions, topography, surface watershed boundaries, land uses near the well and distance from existing supply wells. Avoidance of potential contaminant sources and interference with other well users is a very important consideration when locating new supply wells.

Municipal wells should be hydraulically up-gradient and/or have sufficient buffer distance from potential contaminant sources such as:

- Agricultural sources (runoff from pastures or feed lots, fertilized fields, manure storage areas and intensive pesticide use areas);
- Landfills or waste management facilities;
- Cemeteries;
- Bulk chemical storage facilities (service stations, bulk plants, storage sites);

- Roads and highways (road salt runoff, accidental chemical releases);
- Mines and quarries (stored mine water, acid mine drainage, heavy metals from tailings, mine dewatering activities);
- Wastewater treatment facilities; and
- Industrial activities (manufacturing or processing facilities).

The respective provincial legislation should be consulted to determine required separation distance between wells and specific potential contaminant sources.

Proximity to streams and lakes is a specific consideration with many jurisdictions. The degree of interaction between well field pumping and stream base flows must be addressed through well location, casing length, monitoring of groundwater and stream flow responses, and possibly through model-based assessment.

The location of production wells or a wellfield should also consider the long-term sustainable yield of the host aquifer. A watershed scale water-balance approach or groundwater modeling approach should be applied that considers climate, groundwater and surface water interaction over long time periods.

Identification of a suitable municipal well field location should consider the need for additional wells, based upon growth in water supply demand. Future land use and long term well head protection should also be a factor in selection of a suitable location.

In situations where large quantities of groundwater are required, it may be necessary to locate new wells within a different surface watershed to minimize impacts on existing wells.

If new wells are being added to an existing well field, potential locations should consider interference between new and existing wells. Such effects can have impacts on well performance and long-term operating costs of existing, new and/or future wells.

In addition to the hydrogeological considerations of well or well field location, a public participation process may be needed to both identify the public's concerns, existing land uses and potential hazards, and to assure surrounding well users that their supplies will not be compromised.

2.3.2 Exploration Program

A groundwater supply exploration program will be required to confirm the quantity and quality of groundwater available within a target area.

The exploration program should include, but not be limited to the following:

- Research information on existing wells in the proposed area to help optimize potential drill sites;
- A preliminary assessment of local and regional hydrogeology;
- Selection of drilling sites;
- Exploration drilling; and
- Well and aquifer hydraulic testing.

The program scope will be determined by previous testing work within the area, potential supply sources and water supply requirements.

Initially, one or more test drilling locations should be identified based on various factors (e.g., geology, past exploration work, air photo interpretation, review of regulatory agency information, and proximity to constraints). **Availability of Municipally owned land or proximity to the distribution system, should not be the only criteria used in selection of test drilling locations. Emphasis should be placed on hydrogeology and suitability for long term aquifer protection planning.**

Test drilling should be supervised by a qualified hydrogeologist to ensure that all available geologic and hydrogeologic information, is properly documented. The test hole diameter should suit the individual well yields expected.

In bedrock, water well drilling equipment will be used for test drilling. The minimum test hole diameter should be 150 mm in areas that have not been previously investigated.

In areas having a proven yield, test holes with a minimum 200 mm diameter may be more appropriate, depending upon the supply requirement. If a 150 mm diameter well is used, it can be re-drilled to a larger diameter if sufficient yield is provided.

For screened wells within surficial materials, geotechnical drilling methods should be used for collection of appropriate samples to characterize the aquifer materials and to design the screen. In such cases, and once the screen design is complete, water well drilling equipment will be used to install the screened test well.

During construction of each exploration well, a detailed log should be made for the following:

- Lithology;
- Location of water-bearing zones; and
- Cumulative air-lifted well yield.

Upon completion of each exploration well, the well should be developed by the driller for a minimum 2 hour period with an air lift "blow" test to estimate total yield. A preliminary water quality sample may be taken and analyzed for the full suite of MAC and IMAC aesthetic parameters to confirm presence of suitable water quality.

The completion of the exploratory wells will allow for the determination of aquifer characteristics and well performance characteristics, and ultimately will allow for proper production well design, spacing of wells and pump selection.

2.3.3 Well and Aquifer Yield Hydraulic Testing

Well and/or aquifer hydraulic testing requirements vary by province, and the respective regulatory authority should be contacted to determine the system specific requirements.

Hydraulic testing should consist of the following three components:

- Step-testing, to establish the well's potential yield and drawdown efficiency;
- Constant-rate or constant-drawdown testing for at least 72 hours, or as specified by the local authority; and
- Recovery monitoring for at least 8 hours, or as specified by the local authority, after completion of the long-term pumping test.

All hydraulic testing should be properly supervised by a qualified hydrogeologist to ensure the testing is properly conducted and that all available data is obtained.

Hydraulic testing documentation should include:

- Well owner and location details for all wells involved (Site Map);
- Pumping test operator or sub-consultant details;
- Well identification and construction details (depth, diameter, casing stick up);
- Pump test set-up details (pump size, pump elevation, riser pipe size, flow rate control, power supply used, water level measuring point elevation);
- Type of test (step, constant rate, recovery);
- Number of observation wells;
- Data source (pumping well, observation well, stream station);
- Date and time of when pumping started and ended;
- Static water levels for pumping well and all available observations wells;
- Separation distances between pumping well and all observation wells;
- Time-drawdown and time recovery data forms;
- Water chemistry sampling and laboratory chain of custody forms; and

- Log of field observations, flow adjustments.

Water quality data should be collected during the hydraulic testing.
For a 72 hour test, samples should be collected at intervals as follows:

- Within the first hour;
- Mid-point; and
- At the end of the test.

A suggested sampling protocol is outlined in Table 2.1. A comprehensive set of analyses should be completed on the 72 hour sample to screen for a broad list of possible contaminants. Bacteria testing should only be completed on the 72 hour sample, or as late as practical, to meet lab sample delivery requirements. Field parameters (minimum temperature and electrical conductance) will be monitored at approximate 2 hour intervals as testing proceeds.

Table 2.1 Suggested Sampling Protocol – Groundwater Quality Parameters

	Sample 1 (first Hour)	Sample 2 (Mid-point)	Sample 3 (end of test)
Recommended Analytical Parameter Group (The number of parameters within some analytical parameter groups may vary slightly between laboratories)	RCAp-MS[1] TSS[2]	RCAp-MS[1] TSS[2]	RCAp-MS[1] or equivalent TSS[2] EPA 624[3] Alberta MUST[4] EPA 625[5] Pesticides (OCOP)[6] Gross Alpha, Beta & Gamma[7, 8] Total coliform/e.coli[9]

Notes:

1 – RCAp-MS is a proporietary term and includes a 47 parameter list of major ion, including 23 metals and various physical-chemical parameters. Analysis of all MAC and IMAC parameters may be required by some jurisdictions.
2 – TSS – total suspended solids.
3 – EPA 624 – A series of 35 volatile organic compounds.
4 – Alberta MUST – A series of petroleum hydrocarbon components, including volatile fraction.
5 – EPA 625 – A series of 54 semi-volatile organic compounds.
6 - OCOP Pesticides - A series of 19 oganochlorinate and 48 organophosphate pesticides.
7 – Gross alpha, beta and gamma used as indicators, if elevated, a series of 17 radionuclides are analysed.
8 - Total Uranium and Lead – 210 may be required instead.
9 – Bacteria analyses must include the bacteria count, not just presence/absence.

Hydraulic test results including all time-drawdown, time-recovery and water quality monitoring data, should be clearly documented on appropriate forms, and analyzed by a qualified hydrogeologist.

Analysis of hydraulic response data should be completed using recognized standard procedures (e.g., Theis, Theis-Recovery, Cooper-Jacob, Hantush-Jacob, Hantush-Bierschenk Well Loss), as found in standard reference texts. These procedures may be either applied using manual or electronic methods. Depending on the scope and scale of the pumping test, the analysis should determine:

- Hydraulic properties of the pumping well, specific capacity, safe yield;
- Hydraulic properties (transmissivity and storage coefficient) of the aquifer (from observation well data);
- Sustainable pumping rate for the production well(s);
- Predict operational pumping levels for intended well or well field pumping scenario;
- Recommended pump setting;
- Predict drawdown interference between pumping wells;
- Predict drawdown interference between the well field and the nearest domestic wells;
- Estimate zone of influence and zone of capture for each well using observation well data;
- Estimate sustainable aquifer yield using observation well and water balance approaches;
- Interpret water quality data with respect to drinking water standards and guidelines; and
- Recommend which parameters require treatment where warranted.

The well driller should take precautions to prevent a well from flowing out of control, particularly in areas that have a history of flowing wells.

The recommended pumping rate, along with projected time-drawdown water levels, should be used in pump selection and setting specifications. If appropriate, additional long-term testing may also be included as part of the well commissioning process.

Hydraulic testing data and analysis, including water quality results, should be submitted to the regulatory agency and proponent.

An application to the appropriate regulatory agency is required for groundwater withdrawal. Upon review and acceptance by the regulatory agency, an appropriate permit may be issued.

2.3.4 Groundwater Quality

Groundwater quality is a critical criteria, in both initially selecting the water supply aquifer and for monitoring possible well field water quality changes over time.

Criteria for petroleum hydrocarbons should be used to evaluate petroleum hydrocarbon related quality results. The regulator should be consulted for advice on use of other criteria for which no GCDWQ values exists.

The water quality data collected during the hydraulic testing program should be reviewed and compared to the GCDWQ and hydrocarbon values. In situations where the GCDWQ values are exceeded, the hydrogeologist should indicate if this represents one or more of the following:

- A natural condition-within the aquifer due to:
  - Type of aquifer (e.g., shallow unconfined gravel aquifer, deep confined fractured bedrock);
  - Aquifer vulnerability to land use impacts;
  - Hydrogeochemistry of the water bearing unit (e.g., limestone, gypsum, mineralized zones);
  - Groundwater-surface water interactions (e.g., stream, lake, wetland or seawater intrusion).
- Non-point source impacts from local land uses or contaminants;
- Depth from which groundwater is being withdrawn (e.g., hardness, TDS or presence of reducing conditions); and
- Other impact/source.

The results of this assessment should be included in the hydraulic testing report.

All groundwater quality testing associated with a municipal groundwater supply should be performed by a laboratory that has Canadian Association of Environmental Analytical Laboratories/Standards Council of Canada (CAEAL/SCC) accreditation for the analyses they are undertaking.

2.3.5 Water Treatment

The need for treatment of water quality parameters such as hardness, iron, manganese, arsenic or radiological substances (e.g., uranium, lead 210, radon) will be assessed based on water samples collected during the hydraulic testing. Based upon those results, additional water quality sampling may be required before the treatment process can be designed.

Barring system specific exceptions, groundwater should be disinfected as per Section 4.6.

2.3.6 Well Construction

Wells addressed by this manual include either drilled wells in bedrock or screened wells in surficial materials.

Other groundwater sources such as dug wells, sand points and springs, may be considered by local jurisdictions based on project detail land local conditions. Such sources, however, may be considered to be surface water supplies, and may require treatment in compliance to surface water standards.

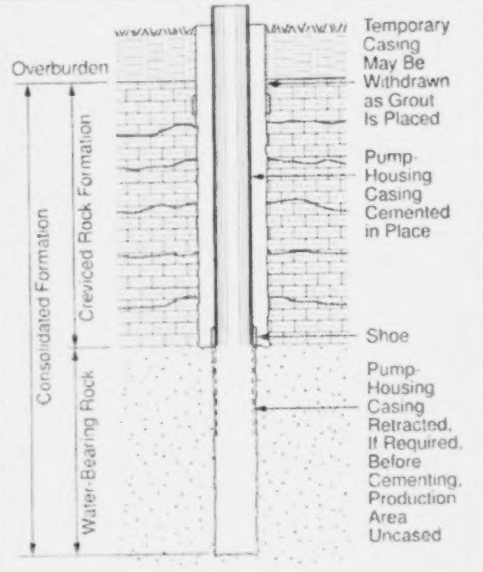
All municipal water wells will be constructed by a water well driller licensed to operate in the province in which they are working.

All well construction work should be properly supervised by qualified personnel. A construction log of each well should be developed showing geologic, hydrogeologic and construction details. A copy of each well log should be provided to the regulatory agency and to the proponent.

Well construction should follow the AWWA Standard for Water Wells and/or the Guidelines for Water Well Construction, as recommended by the Canadian Groundwater Association (1995). Additional criteria may also apply by the regulator, as appropriate.

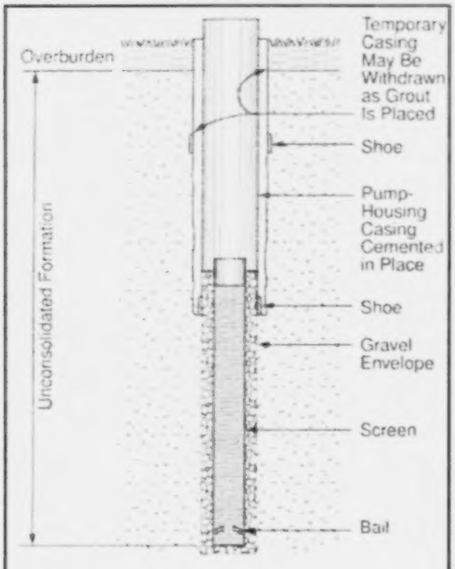
Figure 2.1 provides an example of bedrock well construction, while Figure 2.2 provides an example of a surficial well construction. Both figures are from AWWA A100-97).

Figure 2.1 Example of Bedrock Well Construction


Temporary Casing May Be Withdrawn as Grout Is Placed
Overburden
Pump-Housing Casing Cemented in Place
Consolidated Formation
Creviced Rock Formation
Shoe
Water-Bearing Rock
Pump-Housing Casing Retracted, If Required, Before Cementing. Production Area Uncased

Well with open hole completion in consolidated rock and well casing cemented in place

Figure 2.2 Example of Surifical Well Construction


Temporary Casing May Be Withdrawn as Grout Is Placed
Overburden
Shoe
Pump-Housing Casing Cemented in Place
Unconsolidated Formation
Shoe
Gravel Envelope
Screen
Bail

Gravel packed well with telescoped screen, well casing cemented in place, and gravel envelope terminated above the top of screen.

All wells will be straight and meet plumbness requirements, as specified by AWWA.

Toxic fluids should not be used in the construction of wells. Use of any additives other than water, during well construction must be approved by the regulator.

Basic requirements for municipal well construction are outlined below.

2.3.6.1 Casing

Casing provides the first level of protection to the water supply system from potential surface-source contamination.

Permanent steel or nonferrous casing pipe should be as per AWWA or ASTM specifications, or regulatory agency requirements.

New casing should be used for all municipal wells. Used casing pipe may only be used for exploration well or monitor well construction with approval of the regulator. Temporary casing, if used during well construction, should be removed prior to well completion.

The well and casing diameters should be based on the intended use (production or observation well), anticipated flow rates, pumping equipment specifications, well head completion appurtenances, and screen-liner requirements. Typical well completion diameters for municipal wells should be 200, 250 mm and 300 mm. The minimum casing diameter should be 203 mm to provide sufficient size for pumps and monitoring devices, and contingency for possible future liner installation.

Unless bedrock is encountered close to the surface, a minimum casing length of 12 m, with a minimum of 6 m below the top of bedrock, should be used. A new casing shoe should be used in construction of all municipal wells, unless directed otherwise by the hydrogeologist (e.g., temporary casings, outer grouted casings).

2.3.6.2 Stabilization Liners

Permanent steel or nonferrous stabilizing liners may be required in bedrock where the borehole or water bearing formation is not stable. Stabilizer liners should consist of one of the following:

- Steel or PVC pipe one nominal diameter smaller than the casing diameter with slotted zones across major water-bearing zones;
- Continuous slotted pipe; and
- Gravel-pack stabilization with a pipe and screen liner with sand or gravel filling an annular space between the liner and the borehole walls.

Design, installation and hydraulic development of stabilization liners will be directed by a qualified hydrogeologist.

2.3.6.3 Grouting

All permanent casings should be grouted into place using AWWA specifications.

Grout should consist of 25 to 30 % by volume bentonite grout, unless otherwise requested or approved by the regulator.

Grout should be introduced under pressure from the bottom upward in a continuous operation to ensure a complete seal. Grout should be installed using a pump, using the tremmie method for larger wells, or by positive displacement method for smaller wells. Grout should extend from the bottom of the casing to a point immediately below the pitless adapter connection. A minimum borehole annulus of 50 mm is recommended.

2.3.6.4 Well Screens

All screened wells must be properly designed, based upon AWWA or other specifications, as approved by the regulatory agency. Only new, manufactured wire-wound V-notch stainless steel screens should be used.

Screen slot sizes should be designed based on grain size gradation data, and depending on whether the well is to be a natural or graded gravel pack completion. The diameter, length and screen slot sizes should be designed to maximize pumping efficiency based on the aquifer hydraulic properties, and the required well yield.

Either pipe-sized or telescopic types of screens may be used in screen well construction. For telescopic screens, an elastomeric seal should be installed and extended at least 1.5 m into the overlying permanent casing. No lead packers should be used. All telescopic screens should be equipped with a bail-bottom.

Gravel or sand pack materials will be new, clean-washed material. Material size should be specified based upon grain size analysis of samples from the formation in which the screened well is installed. A minimum annular space of 50 mm will be used around the screen for installation of the pack.

2.3.6.5 Well Development

All wells should be sufficiently developed by surging or bailing to optimize yield and water quality, and to render the borehole as hydraulically efficient as practical. Development will meet AWWA specifications, or as directed by the hydrogeologist.

2.3.6.6 Disinfection

Upon completion, all wells should be disinfected with a chlorine solution to remove microbial pathogens that may have been introduced during well construction. The regulatory agency should be contacted regarding chlorination procedures and the requirements for the disposal of chlorinated water.

Disinfection agents are potentially hazardous compounds. Proper storage, training and handling are required for all disinfection compounds.

2.3.6.7 Abandonment

An open or unused well is a potential liability to any well field. Unless used for monitoring, all test holes, wells or partially completed wells should be properly abandoned as per the requirements of the regulatory agency.

All pumps, wire, and piping will be first removed from the borehole. Prior to sealing, the well depth should be confirmed to check for obstructions or partial formation collapse. If obstructions are encountered, they should be removed prior to abandonment.

Cement grout or bentonite should be used as sealing materials. Placement should be from bottom upward, by methods that avoid segregation or dilution of material. Abandonment may involve alternate placement of grout and clean silica aggregate in a manner that simulates the natural formation stratigraphy, and prevents vertical movement of groundwater along the borehole between water-bearing formations or fractures. Well abandonment should be supervised by qualified personnel.

If the casing is to be left in place, the grout should extend across the bottom of the casing.

Proposed abandonment procedures should be approved by the regulator. The procedure used should then be documented and submitted to the regulatory agency and to the proponent.

2.3.7 Pump Hydraulics

Pump specifications for a newly designed well should be based upon analysis of the hydraulic testing results, and the recommended pumping rates (i.e., short and long-term) and pump intake setting. Factors that will be included in selection of an appropriate pump size include:

- Well and/or casing diameter;
- Predicted sustainable well yield;
- Predicted or observed water level during pumping;
- Total dynamic head and vertical lift requirements;
- Friction/head losses;
- Service pressure; and

- Long-term power requirements.

Municipal wells should be equipped with either submersible or vertical turbine line shaft pumps.

Due to the sensitivity of well specific capacity to fracture dewatering or screen dewatering, the pumps should not be oversized.

Oversizing a pumping system will result in an excessive pumping rate. In turn, the excessive pumping rate can cause critical fracture zones to de-water, resulting in sudden declines in pumping levels and potential damage to the well or pump.

Where multiple wells are proposed, blending characteristics of the water should be considered.

2.3.8 Wellhead Requirements

Wellhead completion consists of either above ground or below ground structures. The selection of the wellhead should be based on the following:

- Presence of existing facilities (e.g., treatment, monitoring, telemetry);
- Design of associated distribution control and/or treatment facilities;
- Water level conditions or artesian pressure;
- Completion appurtenances;
- Well maintenance and/or servicing requirements;
- Wellhead flow metering;
- Capacity for manual water level monitoring;
- Capacity for water sample collection at the well head; and
- Well instrumentation requirements (e.g., water level tube, down-hole pressure/water level transducers for SCADA monitoring and telemetry).

All well heads must be clearly accessible for routine pump servicing and well rehabilitation by heavy equipment.

A pitless adapter well head completion is preferred and is recommended in cases where high water table or flooding risk occurs.

Provision should be made for manual monitoring of water levels within a separate tube (i.e., minimum 25 mm ID) attached to the pump riser assembly in each production well. A separate tube should also be used for installation of down-hole pressure (water level) transducers for SCADA monitoring.

2.3.8.1 Discharge Piping

Discharge or riser piping should meet AWWA or ASTM specifications for water supply pipe.

Discharge piping should be designed to minimize friction losses, and be equipped with the following:

- Check valve;
- Shutoff valve;
- Pressure gauge;
- Total or accumulating flow meter; and
- In-line water sampling tap, located where positive pressure is maintained.

Flow regulation control valves should be provided to permit routine specific capacity pumping testing and control at each well.

Discharge piping will be provided with a means of pumping the well to waste. This is an important precaution to be applied when a well has been "rested" for a period of time, to prevent release of sediment and discoloration into the distribution lines.

Discharge piping should be protected against entrance of contaminants, and any potential egress to a production well elevation will be above the 100 year flood level.

Where above-ground discharge is provided, control values should be located above the pump house floor. Exposed piping, valves and appurtenances should be protected against freezing and physical damage.

2.3.8.2 Pitless Well Head Completion

Shop-fabricated pitless adapter units constructed of materials and weighing at least equivalent or comparable to the well casing, should be used for wellhead completions.

Pitless adapter units should be of watertight construction to prevent entrance of contaminants, and should extend to above the 100 year flood level.

Pitless units should make provision for an access tube within which water levels can be independently measured.

Design will allow for a properly constructed, water tight and vermin-proof casing vent.

2.3.9 Aquifer Protection Monitoring

While detailed well head and aquifer protection planning is not included in this design manual, it is recommended that a municipal well field completion include a provision for routine surveillance of water levels and water quality in both the pumping well and the host aquifer. The regulatory agency should be contacted for their requirements.

2.3.9.1 Observation Wells

Provision should be made for an appropriate number of observation or monitoring wells. The intent of such wells is to allow appropriate monitoring of production well performance, to confirm the extent of pumping influence and drawdown interference between wells, and to detect potential migration of contaminants towards the well.

Design of observation wells will be generally similar to the criteria used for the production wells. Wells drilled during the exploration program can be used or renovated for use as observation wells. At a minimum, all monitoring wells should have 12 m of grouted casing, and be completed with above grade water-tight, vermin-proof well seals. All well heads must be above the 100 year flood stage.

The required number and location of observation wells should be based on hydraulic testing results. One observation well should be located within 10 m of each production well to assess production well efficiencies and long-term well performance.

At least one monitoring well should be located in the mid-point of a well field, for surveillance of long term and seasonal water level responses within the aquifer. This monitoring well should be equipped with an automated water level recording device.

If applicable, a monitor well should be located between the pumping well(s) and any perceived contaminant risk. Where dewatering of domestic wells is of concern, a monitoring well resembling the domestic well design should be established between the pumping well(s) and the domestic well(s) of concern. Alternately, the nearest domestic wells may be incorporated into the well field monitoring strategy.

2.3.9.2 Well Head Protection Plan

A Wellhead Protection Plan (WPP) should be prepared to provide long term management and protection of the groundwater supply. This plan is generally comprised of monitoring, management and maintenance components. Where appropriate, the local authority should be consulted for specific requirements.

2.3.10 Well or Well Field Commissioning

Commissioning of new wells should take place following connection to the distribution system and installation of all well appurtenances. Operation and performance of all well system components should be checked against the system design.

During commissioning, further yield and time-drawdown data may be collected, to support calculated sustained yields and predicted pumping levels, and/or to confirm groundwater quality results. The groundwater quality results should be demonstrated to the regulatory authority. These results may be used to finalize the operational groundwater monitoring plan.

The water level and quality responses of each well should be clearly documented during the commissioning process. A recommended procedure for a multiple well system is as follows:

- Operate the first well for one to three days or until steady state drawdown is achieved;
- Turn on and operate the remaining wells with continued monitoring of water level changes in all wells; and
- After all wells have been turned on, operate the system for a period sufficient to confirm predicted parameters.

All new production wells or well fields should be monitored closely during the initial year of operation. The water level, flow rate and water quality data should be reviewed by a qualified hydrogeologist, and recommendations then made for adjustments or further monitoring as warranted.

2.4 SOURCE WATER PROTECTION

The protection of the source water is an essential component of the development of a water supply development. The local authority should be consulted to determine specific requirements.

In general, the components of a source water protection plan include the following:

- Appropriate inventory and characterization of the source;
- Development of an up-to-date inventory of all sources of pollution affecting the services;
- Quantification of the type of pollutions discharged; and
- Development of goals and implementation of strategies for protecting, monitoring, and evaluating the source.

Chapter 3.0 DESIGN OF WATER TREATMENT FACILITIES

3.1 DESIGN BASIS

3.1.1 Design Flows

Water treatment facilities should be designed such that major process equipment and facilities are capable of supplying the maximum day demand for the 20 to 25 year projected design flows, plus an additional amount that will be sufficient to accommodate plant losses. Maximum Day demand is the maximum amount of water supplied to the system on any given day within a calendar year. Peak flows are the short-term flows expected to be experienced by a particular component of the system and will govern the sizing of many system components.

Minor process equipment such as piping, valves and chemical feed systems should be designed to accommodate future design flow, within the life expectancy of the components. Water treatment facilities should be designed to facilitate future expansion, if necessary. In each case, the designer may consider modularity and expandability as an option to the provision of surplus capacity.

3.1.2 Target Contaminants and Process Selection

Typically, the target contaminants will be identified and the process selection will be conducted in a *Pre-Design Report*. The process selection should take into consideration the ability to satisfy all Maximum Acceptable Concentrations (MACs), Interim Maximum Acceptable Concentrations (IMACs) and Aesthetic Objectives (AOs) recommended in the *Guidelines for Canadian Drinking Water Quality* (GCDWQ).

The designer should confirm the *Pre-Design Report* findings prior to design of a new water treatment facility. Process design criteria should also be identified in a *Pre-Design Report*. If these critical pieces of information have not been evaluated in a *Pre-Design Report*, then such a report should be completed prior to undertaking detailed design.

3.1.3 General Redundancy Requirements

Water treatment plants should be designed in a multi-train system to enable the facility to be operated during periods in which one train needs to be taken off-line for servicing.

Firm pumping capacity is the pumping capacity available with the largest pump out of service. Sufficient redundancy should be provided to ensure firm pumping capacity meets maximum day demand.

A back-up disinfection system should be provided to ensure adequate disinfection is provided during times when the main disinfection system is out of service.

3.2 SITE SELECTION

3.2.1 General

New water treatment facilities should be located such that the selected site maximizes the use of existing infrastructure. In some cases, a new water treatment facility may not be located in the vicinity of an existing facility as other sites may be more cost-effective or more attractive from a long-term system development standpoint. Considerations in planning the location of a new water treatment facility should include:

1. Proximity to existing infrastructure;

2. Hydraulic grade lines;

3. Separation distances and future site expansion;

4. Topography and geotechnical investigations;

5. Land ownership; and

6. Site-related life-cycle costs.

3.2.2 Proximity to Existing Infrastructure

The locations of existing infrastructure services are critical in determining the location of a water treatment facility. The facility should be located close enough to maximize the use of these facilities. In the end, the best location will be one that maximizes the use of existing infrastructure while minimizing the costs associated with implementing a plant at a particular site location. Such existing infrastructure may include, but not necessarily be limited to, the following:

1. Proximity of raw water supply: locating a water treatment facility as close to the raw water supply generally maximizes the amount of contact time in the transmission mains;

2. Proximity to existing transmission mains: locating a water treatment facility as close as possible to existing transmission mains will result in lower transmission main extension costs;

3. Proximity to sanitary sewer services: in some instances, existing sanitary sewer services will be close enough to permit discharge of plant wastes to the sewer, which may eliminate the requirement for on-site waste treatment/disposal systems;

4. Proximity to three phase power service: it is advantageous to minimize the amount of power service extensions required; and

5. Proximity to public access routes: locating a water treatment facility in close proximity to public access routes enables efficient and safe chemical and/or equipment delivery, as well as facilitating construction.

3.2.3 Separation Distances and Future Site Expansion

When possible, water treatment facilities should be located a sufficient distance from the nearest neighboring dwelling to allow for possible future facility expansion and to minimize the impacts of the facility on neighboring developments.

3.2.4 Hydraulic Grade Lines

The design of new water treatment facilities should take into consideration the existing and proposed hydraulic grade lines to determine if raw or finished water pumping will be required. The use of gravity flow can often result in lower capital and operating costs, but may restrict the siting of the treatment facility and may not be suitable for use with some treatment processes. Such factors should be carefully considered to determine the best possible hydraulic and siting configuration such that the water quality objectives of the facility are fully met.

3.2.5 Topography and Geotechnical Investigations

Water treatment facilities should be located in areas where the topography is best suited to the facility construction. Topographical surveys should be conducted on the site prior to design of a facility to confirm that the site will be conducive to development.

Site drainage should also be considered in site selection. Water treatment facilities should be located in locations that exhibit relatively good drainage patterns and dry soil conditions. Such locations prevent the possibility of untreated groundwater and/or surface water intrusion into underground conveyance structures. All water facilities should be located above the 100-year return period flood levels.

Prior to final site selection, a geotechnical survey should be conducted on the proposed site. The survey may include a series of test pits and/or boreholes for the purposes of determining the following:

1. Soil types, moisture contents and densities;
2. Soil load-bearing capacities;
3. Depth of water tables;
4. Depth of bedrock; and
5. Assessment for possible contamination.

The number and type of test pits and/or boreholes will vary between sites but should generally cover the entire area to be developed. Test pits and/or boreholes should be located during topographic surveys.

3.2.6 Land Ownership

Land availability is often limited in the locations that are best suited to development and negotiations for purchase are often time consuming. It is recommended that land negotiations begin as early as possible. Geotechnical investigations should also begin as soon as possible to confirm the suitability of the site for development prior to detailed design.

3.2.7 Site-Related Life-cycle Costs

In addition to capital costs, operating costs can also greatly impact the selection of a site for a new water treatment facility. Operating costs differences between sites may include, but not necessarily be limited to, the following:

a) Raw and finished water pumping costs, in terms of both energy and maintenance related costs;

b) 3 phase power requirements;

c) Waste treatment and disposal costs; and

d) Site maintenance costs.

Once all site-related capital and operating costs have been identified, a life-cycle cost analysis should be completed. There are many ways to compare costs on a life-cycle basis, however, perhaps the most common method is to perform a Net-Present-Worth (NPW) analysis. A NPW analysis takes into account both capital and operating costs and calculates the total costs to construct and operate a facility, in current dollars, for a predetermined amount of time. In a NPW analysis, the life expectancy of major equipment is used for the period of analysis and is typically 20 or 25 years for a mechanical facility. An appropriate interest rate should also be selected.

3.3 LAYOUTS

3.3.1 Site Layout

The design should consider the following:

1. Functional aspects of the plant layout;
2. Provisions for future plant expansion;
3. Provisions for expansion of plant waste treatment and disposal facilities;
4. Access roads, driveways and walkways;
5. Site grading and site drainage;
6. Chemical delivery and storage; and
7. Security-related issues (e.g., fence lines).

3.3.2 Building/Plant Layout

The design of the facility should meet all applicable code requirements for the following:

1. Operator Health and Safety;
2. Ventilation;
3. Lighting and Heating;
4. Foundation drainage; and
5. Dehumidification (if required).

Additional items that should be considered in plant/building layouts, include the following:

1. Equipment accessibility for operation, servicing, and removal;
2. Flexibility of operation;
3. Convenience and ease of maintenance;
4. Back-up power requirements;
5. Separation of chemical storage and feeding;
6. Manual overrides for automated controls;
7. Location of electrical controls in cool, dry places;
8. Redundancy and servicing requirements;
9. Spare parts room;
10. Provision for removal of equipment;
11. Drainage of process areas and process piping/conduits;
12. Safety provisions including alarms, railings, etc.; and
13. Potential for cross-connections.

Some chemical feed and/or process areas may have specific requirements. Refer to Chapter 4 for recommendations.

3.3.3 Provisions for Future Expansion

Provisions for future plant expansions should consider:

1. Oversizing of plant piping and conveyance facilities to provide for future projected flow requirements;
2. Use of blind flanges for future process expansion connections;
3. Allocation of additional space in facility superstructures;
4. Building envelope access points for installation of future equipment

5. Sizing of HVAC and electrical systems; and

6. Provision of wall castings for future piping penetrations.

3.4 P&ID DIAGRAMS AND PLANT CONTROL

Process and Identification (P&ID) diagrams should be developed for all water treatment facilities and should be provided in the detailed design drawings. Copies should be made available at the facility for use by operations and managerial staff. P&ID diagrams should include all major and minor processes along with all ancillary process equipment.

All plants should be designed with a user-friendly human-machine interface (HMI) system to facilitate plant operation and on-line monitoring. Equipment status, water levels, pressures and chemical feed rates should all be displayed via an HMI. All automated systems should be designed with manual overrides. Consideration should also be given to remote monitoring capabilities as well as remote operation capabilities. Remote alarms should be provided for critical plant equipment failures as well as individual filter turbidity, finished water turbidity and chlorine residual concentrations.

All electrical controls should be located above grade, in areas not subject to flooding. All control panels should be designed with a minimum of 1 metre separation to nearby structures and/or equipment for personnel access.

3.5 STANDY-BY POWER

Dedicated stand-by power should be provided such that water may continually be fully treated and supplied to meet the average daily demand during power outages. Alternatives to stand-by power may be considered with proper justification by the Authority having jurisdiction

3.6 CHEMICAL FEED FACILITIES

3.6.1 General

3.6.1.1 Plans and Specifications

Plans and specifications should include

a) Description of feed equipment, including minimum and maximum feed ranges;

b) Location of feeders, piping layouts and points of application;

c) Storage and handling facilities;

d) Specifications for chemicals to be used, including NSF approval for use in potable water treatment;

e) Operating and control procedures including proposed application rates; and

f) Descriptions of testing equipment and procedures.

3.6.1.2 Chemical Application

Chemicals should be applied to the water at such points and by such means as to:

a) Ensure adequate preparation of chemical (if required);

b) Deliver the chemical to the point of use in the system;

c) Ensure satisfactory mixing of chemicals in the process water;

d) Provide maximum flexibility of operation through various points of chemical application;

e) Prevent backflow or back-siphonage between multiple feed points;

f) Provide maximum safety to operators;

g) Ensure maximum safety to consumer; and

h) Ensure maximum efficiency of treatment.

3.6.1.3 Equipment Design

General equipment design should be such that:

a) Feeders will be able to supply, at all times, the necessary amounts of chemicals at an accurate rate, throughout the feed range;

b) Materials that are intended to come into contact are resistant to the aggressiveness of the chemical solution;

c) Chemicals that are incompatible are not stored or handled together;

d) All chemicals are transported from the feeder to the point of application in separate conduits;

e) Chemical feeders are as near as practical to the feed point;

f) Chemicals are fed by gravity where possible;

g) Corrosive chemicals are introduced in such a manner as to minimize the potential for cross contamination; and

h) Chemical feeders and pumps should operate at no less than 20% of feed range unless two fully independent adjustment mechanisms (such as pulse rate and stroke length) are provided, in which case the pumps/feeders should operate at no less than 10% of the feed range.

3.6.2 Chemical Feed System Design

Chemical feed systems should be located as close to the point of application as possible to minimize feed runs without compromising delivery access, proper containment, safety and cross contamination control.

3.6.2.1 Number of Chemical Feed Systems

Where chemical feed is necessary for the protection of public health, the following is recommended:

a) Consideration should be given to redundancy and/or spare parts. (Redundancy requirements are discussed in Chapter 4);

b) Where redundancy is provided, the stand-by unit(s) should be of sufficient capacity to replace the duty unit(s); and

c) Where booster pumps are utilized, a redundant pump should be provided;

Separate feeders should be provided for each chemical applied. Spare parts should be available for all equipment components subject to wear and damage.

3.6.2.2 Control of Chemical Feed Systems

Features of the control of chemical feed systems should consider the following:

a) Feeders may be manually or automatically controlled;

b) Automatic controls should be designed with manual overrides;

c) Chemical feed rates should be proportional to metered plant flow rates;

d) Provisions should be made for measuring quantities of chemicals supplied;

e) Coagulant and coagulant aid addition may be controlled, where water quality conditions warrant, by turbidity, streaming current detectors, pH, or some other sensed parameter, in addition to plant flow;

f) Chemical disinfectants should be automatically controlled by monitoring residual disinfectant concentrations in addition to plant flow with appropriate alarms and other procedures to prevent inadequately disinfected water from entering the distribution system;

g) Weigh scales should be provided for plants utilizing chlorine gas cylinders and should be capable of +/- 5 % degree of accuracy and precision; and

h) Weigh scales are recommended for fluoride solution feed systems.

3.6.2.3 Dry Chemical Feeders

Dry chemical feeders should:

a) Measure chemicals volumetrically or gravimetrically;

b) Provide adequate solution water and agitation of the chemical;

c) Provide gravity feed from solution containers; and

d) Provide a dust enclosure and/or collection system.

3.6.2.4 Positive Displacement Metering Pumps

Positive displacement metering pumps should:

a) Be used to feed liquid chemicals only and should not be used to feed chemical slurries;

b) Be capable of operating at the required maximum flow rates against the maximum pressure at the point of injection; and

c) Be outfitted with calibration columns and pressure relief valves.

A minimum of one (1) duty and one (1) stand-by chemical feed pump should be provided for all chemical feed systems that are pumped.

3.6.2.5 Siphon Control

Liquid chemical feeders should be such that chemical solutions cannot be siphoned into the process water, by any of the following:

a) Ensuring injection occurs at a point of positive pressure;

b) Providing vacuum relief; and

c) Providing a suitable air gap.

3.6.2.6 Cross-Connection Control

Cross-connection control should be provided to ensure that:

a) The service water lines discharging to the solution tanks are properly protected from backflow;

b) Liquid chemical cannot be siphoned through solution feeders into the process water as per section 3.6.2.5.; and

c) No direct connection exists between any sewer and a drain or overflow from a feeder, tank or chamber by terminating all piping a minimum of 150 mm from a receiving sewer/waste drain.

3.6.2.7 Make-up Water Supply

Make-up water for chemical feed systems and dilution should be:

a) Ample in quantity and adequate in pressure;

b) Metered;

c) Fully treated and extracted from a source of finished water obtained from a location sufficiently downstream of any chemical feed point;

d) Meet the requirements of the facility water supply as specified in section 3.7.5; and

e) Be protected from backflow and cross-connections as specified in sections

3.6.2.5 and 3.6.2.6, respectively.

3.6.2.8 Chemical Storage Requirements

General chemical storage requirements are as follows:

a) Space is to be provided for convenient and efficient handling of chemicals;

b) Appropriate heating, humidity control and ventilation for specific chemicals to be stored;

c) Adequate delivery/unloading areas are to be provided;

d) Storage tanks and pipelines should not be used for different chemicals;

e) Chemicals should be delivered in unopened or covered containers until transferred into an approved storage unit; and

f) Material Safety Data Sheets (MSDS) for all chemicals utilized should be kept on-site.

Storage requirements for liquid chemicals are as follows:

a) Liquid delivered in either "bulk" or "drum" form is to have a minimum 30 days of chemical storage. Sixty (60) days is recommended for essential systems;

b) Inventory planning should include consideration of winter restrictions and spring road weight restrictions;

c) Bulk and drum systems both require their own handling and storage areas within the plant

d) Bulk systems require containment systems capable of holding up to 150% of the maximum stored volume;

e) Fill connections and piping to be manufactured of material of suitable chemical resistance for proposed treatment chemical;

f) Storage tanks should have a level indicator;

g) Fill piping should be minimum 50 mm diameter; and

h) Bulk liquid storage to provide a minimum 150 % of tanker truck shipping capacity.

3.6.2.9 Solution and Mixing Tanks

Requirements for solution and mixing tanks are as follows:

a) A means of maintaining uniform strength of solution should be provided;

b) Continuous agitation should be provided;

c) A minimum of one (1) solution tank should be provided (two is recommended for redundancy purposes);

d) Liquid level indicators should be provided;

e) Solution/mixing tanks should be covered, including access ports;

f) Subsurface solution tanks should:
  i. Be free from sources of possible contamination; and
  ii. Ensure positive drainage for ground waters, accumulated water, chemical spills and overflows.

g) Overflow pipes should be turned downward, have screened ends and have a free fall discharge and should be installed in a visible location to identify and contain overflows;

h) Acid storage tanks should be vented to an exterior building vent through separate vent pipes that are located far enough from the air intakes (air condition, ventilation, etc.) to prevent contamination of indoor air;

i) Each tank should have a drain valve protected against backflow;

j) Solution tanks should be located within protective curbing so that chemicals from equipment failure, spillage or accidental drainage cannot enter the water in conduits, treatment or storage basins;

k) Construction should be of a material suitable for resistance of corrosion for the chemical being conveyed; and

l) Tankage is to be labeled as per Section 3.12.

3.6.2.10 Day Tanks

Chemicals that have been mechanically mixed in batch tanks are transferred to a day tank. Requirements for day tanks are as follows:

a) Day tanks are to meet the requirements of Section 3.6.2.9;

b) A minimum of one (1) day tank should be provided for each chemical feed system;

c) Day tanks should hold between 24 and 72 hours of chemical supply. For facilities that may not be manned on weekends, consideration should be given to providing 72 hours storage. Some chemicals may become unstable after hydration and manufacturer's written recommendations should be followed in this situations;

d) Day tanks should be outfitted with an accurately calibrated liquid level measuring device;

e) Tip racks and hand/mechanical transfer pumps may be used (mechanical transfer pump systems should be outfitted with a liquid level limit switch and an overflow);

f) Construction should be of a material suitable for resistance of corrosion for the chemical being conveyed;

g) Agitation should be provided if required to maintain chemical slurries in suspension; and

h) Tankage should be labeled as per Section 3.12.

3.6.2.11 Solution Transport

Solution transport piping should be:

a) As short as possible;

b) Easily accessible through the entire length;

c) Constructed of a material suitable for resistance of corrosion for the chemical being conveyed;

d) Protected against freezing;

e) Capable of being cleaned and/or flushed;

f) Designed with consideration given to scale-forming or depositing properties of the solution being conveyed;
g) Should be sloped upward from the chemical source to the feeder when conveying gases; and

h) Clearly colour coded as per section 3.12.

3.6.2.12 Handling

The following is recommended with respect to chemical handling facilities:

a) Carts, elevators, etc., should be provided to facilitate lifting/moving of chemicals and chemical containers;

b) Provisions should be made for disposing of waste bags, drums, etc., such that dust emissions are minimized;

c) Provision such as the following should be made for the proper transfer of dry chemicals from shipping containers to storage bins or hoppers to prevent dust accumulation:
   i. Vacuum pneumatic equipment;
   ii. Closed conveyor systems;
   iii. Enclosures for emptying containers;
   iv. Exhaust fans and dust filters.

d) Floor surfaces should be smooth and impervious, non-slip, and well drained with 75 mm per 3.0 m minimum slope;

e) Floor drains should be discharged to an appropriate waste receiving/disposal system;

f) Vents from chemical feed areas are to be separate from tank vents, are to vent to the facility exterior and should be above grade and remote from air intakes; and

g) Provision should be made for measuring quantities of chemicals used to prepare feed solutions.

3.6.3 Chemicals

3.6.3.1 General

Chemical shipping containers should be fully labeled, including:

a) Chemical name;

b) Purity;

c) Concentration;

d) Supplier name and address; and

e) Date of delivery.

Chemicals and water contact materials should meet ANSI/AWWA quality standards and ANSI/NSF standard 60 or 61 safety precautions.

Provisions should be considered for assay of chemicals delivered.

3.6.3.2 Chlorine Gas

Chlorine gas feed and storage should be enclosed and separated from other operating areas. Some jurisdictions may have specific guidelines for storage, feed, and handling of chlorine, and these should be considered, in addition to the following.

The chlorine room should be:

a) Provided with a shatter resistant inspection window installed in an interior wall;

b) Constructed in such a manner that all openings between the chlorine room and the remainder of the plant are sealed; and

c) Provided with doors equipped with panic hardware, assuring ready means of exit and opening outwards only to the building exterior.

Full and empty cylinders of chlorine gas should be:

a) Isolated from operating areas;

b) Restrained in position to prevent upset;

c) Stored in rooms separate from ammonia storage; and

d) Stored in areas not in direct sunlight or exposed to excessive heat.

Where chlorine gas is used, the room should be constructed to provide the following:

a) Each room should be a gas-tight room, equipped with a ventilation fan with the capacity to provide one complete air change per minute;

b) The ventilation fan should draw air no greater than 150 mm from the floor level *(Alberta)* and as far as practically possible from the air inlet location, with the fan discharge located so as to not contaminate any incoming air supplies;

c) Air inlets should be through louvers near ceiling level;

d) Louvers for chlorine room air intake and exhaust should facilitate airtight closure;

e) Inspection window;

f) Separate switches for the lights and fan should be located outside of the chlorine room and at the inspection window;

g) Outside switches should be protected from vandalism;

h) A signal light indicating fan operation should be located at each set of switches;

i) Vents from feeders and storage should discharge to the outside atmosphere;

j) The chlorine room location should be on the prevailing downwind side of the facility, away from entrances, windows, louvers, walkways, etc.;

k) Floor drains are not recommended however, if necessary, they should discharge to the exterior of the building and should not be connected to any other drainage system. The outlet should be clearly marked and a warning light or audible alarm provided to indicate the presence of chlorine in the outdoor environment;

l) Equipment for the neutralization of chlorine upon automatic detection of chlorine should be provided;

m) Chlorine rooms should be heated to approximately 15°C and should be protected from excessive heat;

n) Pressurized chlorine gas piping should not convey chlorine gas beyond the limits of the chorine room;

o) Should contain a chlorine gas monitoring system;

p) Should contain warning lights or signals in case of emergency; and

q) A balance located in front of the inspection window should be provided.

3.6.3.3 Acids and Caustics

Acids and caustics should be kept in covered, corrosion resistant shipping containers or storage units. Acids and caustics should not be handled or stored in open vessels. Acids and caustics should be conveyed in undiluted form to the chemical point of treatment or day tank.

3.6.3.4 Sodium Chlorite for Chlorine Dioxide Generation

Due to the explosive nature of sodium chlorite, proposals, plans, and specifications for its use should be approved by the Authority having jurisdiction.

Provisions for proper handling and storage of sodium chlorite is recommended and is outlined as follows:

a) Sodium chlorite should be stored:
    i. In a separate room, preferably detached from the main treatment plant building;
    ii. Away from organic materials;
    iii. In non-combustible structures or, water should be provided to keep the area cool enough to prevent heat-induced explosive decomposition of the chlorite.

b) Measures should be taken to prevent spillage and emergency spill procedures should be in place;

c) Storage drums should be thoroughly flushed prior to recycling or disposal;

d) Positive displacement feeders should be provided;

e) Piping for conveying sodium chlorite and chlorine dioxide solutions should be suitable for conveying these compounds and should be oriented so as to prevent the formation of gas pockets;

f) Chemical feeders may be installed in chlorine rooms, provided sufficient space is available;
g) Injection or termination of conveyance piping should be at a point of positive pressure; and

h) Check valves should be provided to prevent backflow of chlorine into the sodium chlorite piping.

3.7 PLANT FACILITIES

3.7.1 Maintenance and Storage Facilities

Adequate facilities should be included for shop space, storage, wash bays and/or maintenance and storage.

3.7.2 Offices and Control Area

An operations/control area should be provided in a separate room. This area should include a personal computer, a Human Machine Interface (HMI), a fax machine and a telephone. Additional offices may be required for plant staff. Security cameras and CCTV monitors, if provided, should also be located in this area.

3.7.3 Washroom Facilities

A minimum of one male and one female washroom facility should be provided. Shower facilities are recommended for plants where 24-hour staffing is provided. Additional facilities should be considered where the number of plant staff warrant. Designers should consult local building and/or plumbing codes for the minimum facilities required.

3.7.4 Lunchrooms

A lunchroom should be provided and should be separate from all control and laboratory areas.

3.7.5 Facility Water Supply

The facility water supply service and the plant finished water sample tap should be supplied from a source of treated water at a point where the last chemical has been added and thoroughly mixed, and the disinfectant contact time has been achieved.

3.8 LABORATORY FACILITIES

3.8.1 General

Each public water supply should have its own equipment and facilities for routine laboratory testing. Laboratory equipment selection will be water quality and process-specific. Portable and/or bench top units will be acceptable. All materials and methods used are to meet current industry standards and should meet the approval of the Authority having jurisdiction. A certified operator should be provided to perform all in-house laboratory testing.

Some jurisdictions may require quarterly confirmation of analytical results from an accredited laboratory, for appropriate QA/QC for continuous on-line instrumentation.

3.8.2 Testing Equipment

As a minimum, the following laboratory equipment should be specified:

1. All water facilities should provide the means necessary for obtaining water quality samples from select locations in both the water treatment plant and the distribution system;

2. Water treatment facilities should have the following bench-top equipment:
   a) Nephelometric turbidity meter;
   b) pH meter;
   c) Free and total chlorine residual analyzers;
   d) Spectrophotometer;
   e) Titration equipment;
   f) Glassware appropriate for preparing reagents and analysis (e.g., pipettes, beakers, volumetric flasks, graduated cylinders, Erlenmeyer flasks);.
   g) Deionized water;
   h) Thermometer;
   i) Fume hood; and
   j) Analytical balance to 0.1 mg accuracy.

3. Surface water treatment facilities utilizing coagulation and flocculation should have jar testing equipment suitable for scale-up to that process which is used in the full-scale plant;

4. Iron and/or manganese removal plants should have equipment capable of measuring iron and manganese to lower detection limits below that of the GCDWQ AOs;

5. Fluoridated water supplies should have equipment capable of measuring fluoride to a lower detection limit below that of the treatment standard;

6. Systems which utilize poly- and/or orthophosphates should have equipment capable of measuring phosphates from 0.1 to 20 mg/L;

3.8.3 Physical Facilities

All water treatment facilities should have sufficient bench space, cabinetry/storage, ventilation, lighting and sinks.

An eye wash station should be provided and should be located such that operators have easy access to the station. Eyewash stations not connected to a potable water system should have a minimum 15 minute flush capacity. Saline solutions should not be used. Permanent eyewash stations should be flushed regularly.

Air conditioning is recommended for all personnel areas.

3.9 MONITORING

3.9.1 Sample Taps and Locations

Sample taps should be provided so that water samples can be obtained from each water supply source and from appropriate locations from each unit treatment process. Taps used for obtaining microbiological samples should be of the smooth-nosed type without exterior threads, should not be of the mixing type, and should not have an aerator, screen, or other such appurtenance.

Wastewater treatment and disposal systems should have sufficient sampling points to ensure that discharge requirements can be maintained.

3.9.2 On-line Monitoring Equipment

Water treatment plants should provide continuous on-line monitoring for the following parameters:

1. All water treatment plants should monitor the following:
    a) Raw and treated water turbidity;
    b) Raw and treated water pH;
    c) Raw and treated water temperature;
    d) Total and free chlorine in treated plant effluent discharge;
    e) All entry point disinfection residuals; and
    f) Plant flows.

2. In addition to the above, surface water treatment plants should also monitor the following:
    a) Clarified (pre-filter), individual post-filter effluent turbidities and

backwash turbidity;

b) Flocculation tank and backwash water pH;

c) Raw and treated water colour.

3. Membrane filtration systems, in addition to the above, should monitor pre- and post-membrane particle counts;

4. Additional on-line monitoring instrumentation should be considered and is encouraged where conditions warrant.

3.9.3 Meters

All water systems should have acceptable means of metering, displaying and recording the amount of water delivered to the distribution system.

3.10 OPERATIONS AND SAFETY

3.10.1 Operation and Maintenance Manuals

An Operation and Maintenance Manual including a parts list and parts order form, operator safety procedures, and operational troubleshooting section should be provided for all equipment and operations pertinent to the facility.

3.10.2 Safety and Hazardous Materials

All water treatment plants should be adequately equipped to meet requirements of the current Occupational Health and Safety Act. All water treatment plant staff should be adequately trained in emergency first aid, confined spaces (if applicable), and Workplace Hazardous Materials Information System (WHMIS). All Material Safety Data Sheets (MSDS) should be made available at the locations in which the potentially hazardous material is used. A safety program is recommended for implementation at all water treatment plants.

In addition to the above, the following operator safety measures are to be employed:

a) Provision should be made for ventilation of chlorine feed and storage rooms as per Section 3.6.3.2.

b) Respiratory protective equipment meeting the Occupational Health and Safety Act, General Safety Regulation – Selection of Respiratory Equipment, should be made available where chlorine gas is handled, should use compressed air, should have a minimum 30 minute capacity, but should not be stored in the location where chlorine gas is handled.

c) Chlorine leak detection should be provided as follows:
   i. Concentrated ammonium hydroxide (56% ammonia solution) should be available for chlorine leak detection;
   ii. Where tonne containers are used, a leak repair kit is required;
   iii. Continuous leak detection equipment is required; and
   iv. Continuous leak detection equipment should be equipped with both audible and visual alarms.

d) An adequate supply of protective equipment should be provided and should consist of:
   i. Minimum one pair of rubber gloves;
   ii. One dust respirator certified for toxic dusts;
   iii. Protective clothing;
   iv. Goggles or face mask; and
   v. Other protective equipment as necessary.

e) Emergency eyewash stations or deluge showers should be provided in areas where strong acids or alkalis are used or stored;

f) Standard Operating Practices (SOPs) should be developed and contingency plans should be documented.

3.11 FACILITY CONSTRUCTION

3.11.1 Basic Materials of Construction

3.11.1.1 Concrete Tankage

Concrete tankage should be cast-in-place, steel reinforced concrete tankage, conforming to current CSA and ASTM standards.

3.11.1.2 Prefabricated Tankage

Painted or epoxy coated steel should be the standard. Stainless steel is recommended for applications where the pH of the liquid in the tankage is less than 5.0. Marine-grade aluminum is also an acceptable tankage material.

3.11.1.3 Superstructure

With the exception of slow sand filtration, all water treatment plants should be housed within a building or superstructure. The superstructure should be designed to have a minimum service life of 50 years and should be designed to meet all current national and local building, plumbing and electrical codes.

Precast or concrete brick and block superstructures are generally preferred over metal or wooden superstructures.

3.11.1.4 Access, Ladders, Catwalks and Stairways

Access hatches, stairways, catwalks and ladders should be provided between all floors, and in any pits or compartments which should be entered. They should have handrails on both sides and treads of non-slip material. Stairs should be the standard between superstructure levels with ladders and access hatches being the standard in chambers/pits/compartments, and catwalks should be the standard between and/or above process tankage. Where cross contamination is a possibility, catwalks should be of the fill type, with a side plate. Stairs should have risers not exceeding 225 mm.

3.11.2 Valves and Piping Materials

Valves and piping materials should be designed taking the quality of liquid to be conveyed into consideration. Acceptable process piping/valving materials include polyvinyl chloride (PVC), polyethylene (PE), ductile iron (DI), carbon steel and stainless steel. Special consideration is to be given the low and high pH liquids. Insulation should be provided where temperatures below 4°C are anticipated.

3.12 LABELING AND COLOUR CODING

To facilitate identification of process piping in water facilities, it is recommended that all piping be labeled. Due to the large number of small diameter chemical feed pipes, it is also recommended that all chemical feed piping be colour-coded. Directional arrows should be provided if flow is unidirectional. Labels and colour coding should adhere to the following colour scheme:

Process Water Piping	
Raw	Olive Green
Settled or Clarified	Aqua
Finished or Treated	Dark Blue
Chemical Feed Piping	
Primary Coagulant (i.e., Alum)	Orange
Ammonia	White
Carbon Slurry	Black
Caustic	Yellow with Green Band
Chlorine (Gas and Solution)	Yellow
Fluoride	Light Blue with Red Band
Lime Slurry	Light Green
Ozone	Yellow with Orange Band

Phosphate Compounds	Light Green with Red Band
Polymers & Coagulant Aids	Orange with Green Band
Potassium Permanganate	Violet
Soda Ash	Light Green with Orange Band
Sulfuric Acid	Yellow with Red Band
Sulfur Dioxide	Light Green with Yellow Band
Waste Piping	
Backwash Waste	Light Brown
Sludge	Dark Brown
Sewer (Sanitary)	Dark Grey
Other Piping	
Compressed Air	Dark Green
Gas	Red
Other	Light Grey

All process piping is to be labeled and, where piping is not necessarily indicated in above, colour coding is to match that of the nearest unit process. All labels to be spaced a maximum of 1.5 metres and to be easily visible. In cases where two colours do not provide sufficient contrast to easily differentiate the two, a 150 mm band of contrasting colour should be on one of the pipes at 750 mm intervals.

3.12.1 Commissioning and Testing

Commissioning and testing is to be carried out as per the requirements of the Authority having jurisdiction. It is recommended that the future water treatment plant operator(s) be present during construction and commissioning and that he/she receive instruction on equipment and processes during facility start-up.

All tanks, pipes and equipment which convey or store potable water should be disinfected in accordance with AWWA procedures as well as the designer's plans and specifications.

3.12.2 Security

All water treatment facilities should be made reasonably secure to prevent public access onto the site using chain-link fencing and gates. Building security is also imperative and locks should be provided on all doors, windows and access hatches. Remote mounted cameras and security systems are also recommended. Access to process tankage and water storage basins should be highly restricted.

3.13 REMOTE OPERATION OF FACILITIES

Remote operation of the water treatment facility using a Supervisory Control and Data Acquisition (SCADA) systems should be considered. The SCADA system should:

a) Be capable of monitoring and recording on-line instrumentation data;

b) Be capable of adjusting set-points of critical functions and key parameters within the plant;

c) Be designed with adjustable alarms for monitoring of critical plant functions and key process parameters and/or equipment status;

d) Be capable of remotely notifying the appropriate individual when the problems arise, in addition to the nature of the problem;

e) Be provided with off-site controls for adjusting of critical plant functions; and

f) Only be provided in-conjunction with an available off-site operator with an adequate response time.

3.14 OTHER CONSIDERATIONS

Consideration should be given to the design requirements and recommendations of all other provincial and national regulatory authorities for such items as safety requirements, handicapped accessibility, plumbing and electrical codes, etc. Consideration should also be given to design standards for specific process requirements, which although beyond the scope of this document, may impact the overall design of the facility.

Chapter 4.0 DESIGN OF WATER TREATMENT PROCESSES

4.1 GENERAL

The design of water treatment processes and devices should depend on the nature and quality of the water to be treated, seasonal variations, and the required finished water quality. Plants designed for processing potable water should:

1. Provide a minimum of two (2) treatment trains, operated in parallel;
2. Be designed to provide a multiple-barrier approach;
3. Minimize hydraulic losses through facilities; and
4. Be started manually following shutdown.

4.2 PRESEDIMENTATION AND SCREENING

4.2.1 Pre-sedimentation

Raw water containing high levels of turbidity may require pre-sedimentation, either with or without the addition of coagulants. Pre-sedimentation basins should:

1. have hopper bottoms or be equipped with mechanical moving sludge removal apparatus;
2. have a means of dewatering the settled sediments;
3. be designed such that the incoming water is dispersed evenly across the tank width to prevent short-circuiting;
4. have provisions for a by-pass around the pre-sedimentation unit; and
5. be designed with a minimum of three (3) hours detention time (actual detention time is to be determined through sedimentation tests).

4.2.2 Screening

Screens should be used upstream of the oxidation/rapid mix units in all surface water treatment plants.

Fine screens should be used prior to headworks of a surface water treatment facility and should meet the following requirements:

1. Provide a screen opening between 150% to 200% of the conveyance channel;

2. Provide a head loss no greater than 1.5 m;

3. Have a mesh between 6 and 9 mm;

4. Have a velocity of the net screen openings not greater than 0.6 m/s at maximum design flow and minimum submergence (lower requirements may be imposed by regulatory agencies for certain species of fish);

5. Be hydraulically cleaned; and

6. Be easily accessible.

Coarse screens (bar and/or trash racks) may be required upstream of fine screens. Coarse screens should be constructed using 13 to 19 mm bars inclined at 30 degrees from vertical, providing 25 to 75 mm openings.

4.3 COAGULATION / FLOCCULATION PROCESS

4.3.1 General Process Description

4.3.1.1 Coagulation

Coagulation refers to the combined processes of rapid mixing and chemical precipitation of dissolved and particulate matter from water through "particle destabilization". Coagulation can be accomplished using inorganic salts (positively charged metal ions such as aluminum and iron) or cationic polymers. Coagulation (or particle destabilization) using inorganic salts occurs by charge neutralization. Rapid blending of coagulant in the raw water using high intensity mixing produces small, destabilized particles, which are ideal for treating many low turbidity, low alkalinity surface waters.

Sweep coagulation refers to the process in which sufficiently high concentration of coagulant are added to precipitate metal hydroxides, which then enmesh floc particles into larger agglomerates during flocculation. Enhanced coagulation refers to the process in which sufficiently high concentration of coagulant are added to optimize the removal of natural organic matter with the goal of reducing or eliminating DBP formation.

4.3.1.2 Flocculation

Flocculation is the process following coagulation which uses gentle stirring to bring suspended particles together so they will form larger, more settleable aggregate particles, called flocs. Organic polymers are often utilized at this stage to provide bridging of floc particles, which tends to form even larger floc agglomerates.

4.3.2 Rapid Mixing

Rapid mixing should be provided for all systems which utilize chemical addition in the form of coagulation and flocculation in the treatment process. Rapid mixing should mean the rapid dispersion of chemicals throughout the water to be treated by agitation. Agitation may be provided through mechanical in-line mixers, static mixers or paddle-type mechanical agitators.

4.3.2.1 Chemical Injection

Chemicals injected to rapid mix units should be injected at a point closest to the inlet of the rapid mix unit. Flocculent aids should not be injected into the rapid mixing unit unless an additional rapid mixing unit for the flocculent aid is provided. Coagulant and coagulant/flocculant aid addition should be derived from jar and/or pilot testing and should not exceed 2 minutes. The nozzle velocity of a chemical injector into a rapid mix unit should not exceed 3.0 m/s.

In-line static mixers are considered suitable for rapid mixing of primary coagulants. Primary coagulants should not be mixed using in-line devices such as pumps, weirs, valves, etc., as they do not provide controlled mixing.

High intensity mixing is not required for secondary chemical addition and should be installed a minimum of 30 pipe diameters or channel widths from the point of coagulant addition (*Alberta*).

4.3.2.2 In-line Static Mixers

In-line static mixers are typically used for charge neutralization coagulation and should be designed to conform to all three of the following standards (*Alberta*):

a) Mixing intensity or velocity gradient (G-value) = 700 – 1500 s^{-1};

b) Retention time (t) = 0.5 – 1.0 seconds; and

c) Gt = 500 – 1500.

4.3.2.3 In-line Mechanical Mixers

In-line mechanical mixers are typically used for charge neutralization coagulation and should be designed to conform to all three of the following standards

(*Alberta*):

a) Mixing intensity or velocity gradient (*G*-value) = 3000 – 5000 s^{-1};

b) Retention time (*t*) = 0.5 – 1.0 seconds; and

c) *Gt* = 2000 – 3000.

4.3.2.4 Paddle-Type Rapid Mixer

Paddle type mixers are typically used for sweep and enhanced coagulation and should be designed to conform to the following standards:

a) Mixing intensity or velocity gradient (*G*-value) = 600 – 1000 s^{-1} (*AWWA, 1998*);

b) Retention time (*t*) = 10 – 60 seconds (*AWWA, 1998*); and

c) *Gt* = 6000 – 25,000 (*Alberta and AWWA*).

4.3.3 Flocculation

4.3.3.1 Flocculation Basins

All flocculation basins should:

1. Be located within a properly designed building;

2. Be designed to minimize hydraulic short-circuiting;

3. Be designed to prevent destruction of floc agglomerates;

4. Utilize a minimum of two-stage flocculation to permit a tapered velocity gradient (three-stage flocculation may be more appropriate depending on the downstream treatment processes utilized;

5. Utilize mechanical or hydraulic flocculation with a minimum total retention time of 30 minutes;

6. Have a flow-through velocity not less than 0.15 m/s and not greater than 0.45 m/s;

7. Have interconnecting piping and conduits designed to provide a velocity not less than 0.15 m/s and not greater than 0.45 m/s;

8. Minimize turbulence at bends and other changes in direction;
9. Be designed to minimize hydraulic losses;
10. Be outfitted with either a drain or a sump for sludge removal;
11. Not be greater than 5 metres in liquid depth;
12. Have a freeboard between 0.3 and 0.5 m;
13. Be equipped with drainage connections;
14. Not be of the diffused air or water jet mixing type for conventional water treatment plants; and
15. Be as close together as possible.

4.3.3.2 Flocculators

Mechanical, paddle-type flocculators should:

1. Be designed to provide a mixing intensity (*G*) of 10 – 80 s^{-1} depending on number of flocculation stages) (*AWWA; Alberta recommends max 50; AWWA selected to offer greater flexibility*);
2. Be designed to provide a total *Gt* of 20,000 – 110,000;
3. Have a maximum peripheral speed of 1.0 m/s;
4. Have variable speed motors consisting of a minimum of three (3) settings;
5. Be manufactured from corrosion resistant materials; and
6. Have a minimum water depth of 3.3 m.

Hydraulic flocculators should:

1. Only be utilized in systems where the anticipated flow variations are small (*Alberta*);
2. Be designed to provide a mixing intensity (*G*) of 5 – 50 s^{-1} (will vary depending on number of flocculation stages), where G can be determined according to

the following formulation at 4°C (*Alberta – AWWA has a similar formula but Alberta manual formula selected for simplicity*):

$G = 12.7 \times (H/t)^{0.5}$

Where G = Mixing Intensity (dimensionless)
H = Headloss (m)
t = Residence time (sec)

3. Have a maximum liquid velocity of 1.0 m/s; and
4. Where mechanical flocculators are used, they should have variable speed motors consisting of a minimum of three (3) settings.

4.4 CLARIFICATION

A method of clarification is typically provided during conventional treatment utilizing coagulation/flocculation processes. Clarification should refer to all methods of removing solids from the process water but should not include filtration processes.

4.4.1 Sedimentation

Sedimentation is the process by which flocculated particles are removed from suspension through settling. Sedimentation basins typically follow the flocculation process. The retention time and loading rates used in a sedimentation basin will largely depend on the nature of the contaminant to be removed from the raw water, the chemicals added during coagulation and type of sedimentation process used. There are many proprietary variations of sedimentation process. The most common forms of sedimentation are:

1. Conventional sedimentation;
2. Plate and tube settlers;
3. Solids contact clarifiers;
4. Upflow sludge blanket clarifiers; and
5. Ballasted flocculation and sedimentation.

4.4.1.1 General

The following should apply to all sedimentation basins:

1. A minimum of two (2) trains should be provided;

2. Basins, piping and appurtenances should be constructed from corrosion resistant materials;

3. Inlets should be designed such that influent water is distributed evenly across the entire basin and at uniform velocities using baffles;

4. Should be designed such that short circuiting does not occur;

5. Outlet weirs or submerged orifices should be designed to:
    a) Not exceed discharge velocities of 250 m^3/day/m;
    b) Have a maximum submergence depth of 1.0 metre;
    c) Not exceed an orifice entrance velocity of 0.15 m/s; and
    d) The use of submerged orifices is recommended in order to provide a volume above the orifices for storage when there are fluctuations in flow.

6. An overflow weir or pipe should be provided to establish the maximum water level desired on top of the filters;

7. A superstructure to house the sedimentation units is recommended;

8. Basins should be designed with a drain or sump and bottom slopes should range from < 1% to 8% for mechanical and non-mechanical sludge collection, respectively;

9. Mechanical sludge collection equipment is recommended;

10. Sludge removal design requirements should be as follows:
    a) Sludge removal piping should be minimum 75 mm diameter;
    b) Entrance to sludge piping should be designed to prevent clogging;
    c) Valves should be located on the basin exterior;
    d) A means to observe sludge levels in-situ should be provided; and
    e) Sludge disposal should be by an approved method as stipulated by the Authority having jurisdiction.

11. Flushing lines should be provided;

12. Handrails should be provided around the basins and ladders should be provided for access into the basins;

4.4.1.2 Conventional Sedimentation

Conventional sedimentation should refer to low-rate sedimentation basins that are constructed without high-rate settling devices. The following design criteria should apply to sedimentation basins used for conventional treatment:

1. Retention time should be between two (2) and four (4) hours for coagulation processes;
2. Retention time should be minimum two (2) hours for lime softening processes;
3. Surface overflow rates should not exceed 1.2 m/hr *(Alberta suggests 0.83 - 2.5, GLUMRB was selected as 1.2 corresponds with AWWA/ASCE, 1998)*;
4. Flow through the basin should be laminar and velocities through the sedimentation basin should not exceed 0.15 m/min (GLUMRB AWWA/ASCE recommends 0.6 – 1.2 m/min; GLUMRB selected for conservancy);
5. Water depth should be 3.0 – 5.0 m, with 0.6 – 1.0 m freeboard (*Alberta*);
6. Minimum length: width ratio = 4:1 (5:1 is recommended) (*Alberta*);
7. Inlet/outlet weir loadings rates may be as high as 360 m^3/day/m (*Alberta; GLMURB suggests 175-350; Alberta selected as agrees with AWWA/ASCE, 1998*); and
8. Should meet the requirements of Section 4.4.1.1.

4.4.1.3 Plate and Tube Sedimentation

Plate (or tube) sedimentation should refer to high-rate sedimentation processes that are constructed with high-rate settling devices. The following design criteria should apply to plate (or tube) sedimentation basins:

1. Surface overflow rates should not exceed 4.8 m/hr *(Alberta suggests 5.0 - 6.3, GLUMRB at 4.8.)*;
2. Application rates for plates (or tubes) should not exceed 1.2 m/hr, based on 80% of the horizontal projected area;
3. Water depth should be 3.6 – 5.0 m, with 0.6 – 1.0 m freeboard;

4. Inlet and outlet considerations – Maintain velocities suitable settling in the basin and minimize short-circuiting, with plate units designed to minimize maldistribution across the plates;

5. Drain piping from the settling units should be designed to facilitate flushing of the basins;

6. Should meet the requirements of Section 4.4.1.1; and

7. Proprietary designs that do not meet these requirements should be subject to pilot testing requirements as per Section 2.2.3.2.

4.4.1.4 Solids Contact Clarifiers

Solids contact clarifiers (or reactor clarifiers) refer to high-rate flocculation and sedimentation processes whereby a sludge return feed is introduced into the clarifier. The following design criteria should apply to solids contact clarifiers:

1. Solids contact clarifiers should be subject to pilot testing requirements as per Section 2.2.3.2;

2. Solids contact clarifiers should be designed for the maximum flow rate and should be adjustable to changing flow rates and water quality;

3. Flocculation time should be minimum 30 minutes and in a separate tank or in a baffled chamber (*Alberta recommends 20-40 min*);

4. Surface overflow rates should not exceed 1.2 m/hr *(Alberta suggests < 6.0; AWWA/ASCE recommends 1.2 – 3.7; GLMURB suggests 2.4-4.2; 1.2 was selected as appropriate for colder, low turbidity, highly coloured water as found in the Atlantic Provinces)*;

5. Tubes may be used to increase loading rates and should meet the requirements of Section 4.4.1.3;

6. Retention time should be two (2) to four (4) hours (*GLUMRB; Alberta recommends 1-2 hrs; GLUMRB selected*);

7. Should have a means of measuring solids concentration and collecting sludge in the central flocculation zone;

8. Softening units should be designed such that continuous slurry concentrations of 1% or greater (by weight) can be maintained;

9. Total water loss should not exceed 5% for clarifiers and 3% for softening units;

10. Sludge waste concentration should not exceed 3% for clarifiers and 5% for softening units;

11. Slurry recirculation rate should be 3 – 10 times the raw water flow rate; and

12. Should meet the requirements of Section 4.4.1.1.

4.4.1.5 Upflow Sludge Blanket Clarifiers

Upflow sludge blanket clarifiers should refer to high-rate flocculation and sedimentation processes whereby a flocculation and sedimentation occur simultaneously in the clarifier. The following design criteria should apply to upflow sludge blanket clarifiers:

1. Upflow sludge blanket clarifiers should be subject to pilot testing requirements as per Section 2.2.3.2;

2. Upflow sludge blanket clarifiers should be designed for the maximum flow rate and should be adjustable to changing flow rates and water quality;

3. Flocculation time should be minimum 30 minutes and in a separate tank or in a baffled chamber;

4. Surface overflow rates should not exceed 2.4 m/hr *(Alberta suggests < 3.0; AWWA/ASCE recommends 2.4 – 3.0; 2.4 was selected as appropriate for colder, low turbidity, highly coloured water as found in the Atlantic Provinces);*

5. Tubes and/or plates may be used to increase loading rates to 4.9 m/hr, however, pilot testing should be conducted as per Section 4.4.1.3;

6. Retention time should be one (1) to two (2) hours;

7. Should have a means of measuring solids concentration and collecting sludge in the central flocculation zone; and

8. Sludge waste concentration should not exceed 3% for clarifiers and 5% for softening units;

9. Should meet the requirements of Section 4.4.1.1.

4.4.1.6 Ballasted Flocculation

Ballasted flocculation refers to the high-rate flocculation and sedimentation processes whereby sand is used as a seed for floc formation in the flocculation process. The sand provides surface area that enhances flocculation and acts as a ballast or weight. The resulting sand ballasted floc allow for clarifier designs with high overflow rates and short retention times. The ballasted flocculation process is well suited for difficult to treat waters such as those with rapidly fluctuating source water quality. These systems are proprietary in nature, however, the following general guidelines should apply to adsorption contact clarifiers:

1. Solids contact clarifiers should be subject to pilot testing requirements as per Section 2.2.3.2;

2. Solids contact clarifiers should be designed for the maximum flow rate and should be adjustable to changing flow rates and water quality;

3. Tubes may be used to increase loading rates and should meet the requirements of Section 4.4.1.3;

4. Should have a means of recycling and cleaning sand ballast for reintroduction to the flocculation process; and

5. Should meet the requirements of Section 4.4.1.1.

4.4.2 Dissolved Air Flotation

Dissolved air flotation (DAF) is the process by which flocculated particles are removed from suspension by floating them to the surface of the clarifier using microbubbles. DAF systems typically follow flocculation and should be considered as an acceptable alternative to sedimentation processes. The retention time and loading rates for DAF will largely depend on the nature of the contaminant to be removed from the raw water, the chemicals added during coagulation and type of sedimentation process used.

4.4.2.1 General

The following should apply to all DAF systems:

1. A minimum of two (2) trains should be provided;

2. Basins, piping and appurtenances should be constructed from corrosion resistant materials;

3. Inlets should be designed such that influent water is distributed evenly across the entire basin and at uniform velocities;
4. Should be designed such that short circuiting does not occur;
5. An overflow weir or pipe should be provided;
6. A superstructure to house the DAF units should be provided;
7. Basins should be designed with a drain or sump and bottom slopes should be minimum 0.5%;
8. Mechanical float removal equipment should be provided and should be discharged to a sludge hopper;
9. Sludge disposal should be by an approved method as stipulated by the Authority having jurisdiction; and
10. Handrails should be provided around the basins and ladders should be provided for access into the basins.

4.4.2.2 Design Criteria

The following design criteria should apply to DAF clarification systems:

1. An inlet baffle should be provided and is to be placed at a minimum of 45° from horizontal (60° to 75° is recommended) (*Alberta*);
2. Surface overflow rates should not exceed 9.6 m/hr (higher loading rates should be pilot tested as per the requirements specified in Section 2.2.3.2) *(Alberta suggests 5 – 15; AWWA/ASCE recommends 9.6-12.0; 9.6 m/hr or 4.0 Usgpm/sf was selected as typical for most DAF systems designed in Atlantic Canada);*
3. Cross flow velocities between the top of the influent weir and the liquid surface should be between 0.7 and 1.0 m/min (*Alberta*);
4. Tank depth should be between 2.0 m and 3.0 m (*Alberta = 2 m; AWWA/ASCE = 3 m*);
5. Tank length should be no greater than 12.0 m (*AWWA*);
6. The clarified water should be collected at the bottom of the clarifier and discharged over a water level control weir to maintain the water level in the clarifier;

7. The recycle flow should be introduced at such a location to ensure even distribution of the released air at the tank influent;

8. Bubble diameter should be between 10 μm and 100 μm *(Alberta recommends 20-100)* and average approximately 40 – 50 μm *(AWWA/ASCE)*;

9. Recycle ratio should be between 5% *(AWWA/ASCE)* and 12% *(Alberta)* and is typically around 10%;

10. Saturation pressure should be 450 kPa to 725 Kpa (*Alberta*; AWWA/ASCE recommends 414 – 620);

11. Air concentration in the process tank after injection should be between 8 mg/L and 10 mg/L (*Alberta*);

12. Air injection should be designed to ensure an even distribution of air across the inlet baffle;

13. Air and recycle ratio should be adjustable; and

14. Should meet the requirements of Section 4.4.1.1.

4.4.3 Adsorption Clarification

Adsorption clarification is a high-rate treatment process that uses a combination of hydraulic flocculation/roughing filtration and rapid rate filtration.

As the coagulated water passes upward through the roughing filter, the floc agglomerates increase in size and are removed/adsorbed by the coarse media. These systems are more often applicable for higher quality surface water with low turbidity, iron, manganese and colour. The limited flocculation time typically provided in these systems can be a concern at low raw water temperatures.

These systems are proprietary in nature, and the following guidelines generally apply:

1. The units should be subject to pilot testing requirements as per Section 2.2.3.2;

2. The units should be designed for the maximum flow rate and should be

operated within the range of 50% to 100% of the design capacity;

3. The surface overflow rates should be in the range of 19.5 to 25.5 m/hr *(AWWA/ASCE)*;
4. The filtration zones should be backwashed using air scour; and
5. The requirements of Section 4.4.1.1 should be met.

4.5 FILTRATION

Barring system specific exceptions, filtration shall be provided for all supplies treating a surface water or a groundwater under the direct influence (GUDI) of surface water. Acceptable filtration processes include, upon the discretion of the reviewing Authority, the following:

1. Rapid rate gravity filtration;
2. Rapid rate pressure filtration;
3. Diatomaceous earth filtration;
4. Slow sand filtration;
5. Direct Filtration;
6. Deep bed, rapid rate gravity filtration;
7. Biological filtration;
8. Membrane filtration; and
9. Bag and cartridge filtration.

The use of any of the above processes should be supported by operating and water quality data over a reasonable period of time in a similar process configuration to support its use. Experimental and/or pilot studies may be required for some filtration options under certain conditions.

4.5.1 Rapid Rate Gravity Filtration

4.5.1.1 Pretreatment

Rapid rate gravity filters should have pretreatment in the form of coagulation/flocculation and clarification, and should meet the requirements of Section 4.3. Clarification is not required for those filters operating in "direct filtration" mode (See Section 4.5.3 for Direct Filtration requirements).

4.5.1.2 Rate of Filtration

Rapid gravity filters should be designed to provide a rate of filtration not greater than 9.0 m/hr (*Alberta and AWWA/ASCE*). The actual rate of filtration should be determined through consideration of such factors as raw water quality, degree of pretreatment, filter media, water quality control parameters, competency of operating personnel, and other factors as required by the reviewing authority. In any case, the filtration rate should be justified by the designing engineer to the satisfaction of the reviewing authority prior to the preparation of plans and specifications. Filtration rates higher than those identified herein may be subject to the pilot testing requirements of Section 2.2.3.2 (*Alberta and AWWA/ASCE*).

4.5.1.3 Number of Units and Redundancy

A minimum of two (2) filtration units should be provided. The filters should be designed to enable the facility to operate with one filter out of service provided that provincial health related water quality requirements are met while one filter is out of service.

Where declining rate filtration is used, the variable aspect of filtration rates and the number of filters must be considered when determining the design capacity of the filters.

The respective provinces should be contacted for specific redundancy regulations and requirements.

Piping systems should be designed to accommodate flows up to 50% greater than the design capacity of the filters so as to accommodate potential peak demands or future expansion (*Alberta*).

4.5.1.4 Headloss and Control

Filters should be designed with a maximum permissible headloss not greater than 2.5 m and a clean bed headloss of not less than 0.3 m. Filters should be designed to have at least 1.0 m of water above the media and in the case of high rate filtration, this value should not be less than 1.5 m.

Filter run times should be designed between 12 and 72 hours (*Alberta*) and, where possible, should be between 24 and 48 hours. Longer filter run times may be considered provided that it is adequately demonstrated that adverse impacts on water quality, and operation and maintenance of the filter will not result.

4.5.1.5 Structural and Hydraulic Details

The structural and hydraulic design should provide for the following:

a) Vertical walls within the filter;

b) No protrusion of filter walls into the filter media;

c) The units should be covered by a super structure;

d) Headroom should permit normal inspection and operation;

e) The minimum depth of filter box should be 2.6 m;

f) The minimum water depth over surface of media should be 1.0 m;

g) The effluent pipe should be trapped to prevent backflow of air to the bottom of the filters;

h) Prevention of floor drainage to the filter with a minimum of 100 mm curbing around the filters;

i) Prevention of flooding by providing an overflow;

j) Maximum velocity of treated water in pipe and conduits to filters of 0.6 m/s;

k) Cleanouts and straight alignment for influent pipes or conduits where solids loading is heavy, or following lime softening;

l) Washwater drain capacity to carry maximum flow;

m) Walkways around filters should be not less than 0.6 m wide;

n) Safety handrails or walls should be placed around all filter walkways; and

o) The units should be constructed to prevent cross connections and common walls between potable and non-potable water.

Washwater troughs should be constructed to have:

a) The bottom elevation above the maximum level of expanded media during washing;
b) 50 mm freeboard at the maximum rate of wash;
c) The top edge level and at the same elevation;
d) Spacing so that each trough serves the same number of square metres of filter area; and
e) The maximum horizontal travel of suspended particles to reach the trough should not exceed 1.0 m.

4.5.1.6 Filter Media

Filters should be dual- or multi-media type, and should be constructed of natural silica sand or other natural synthetic approved media, meeting the following requirements:

1. The total depth of media should not be less than 600 mm and not more than 750 mm;
2. The effective size of the smallest media should be between 0.45 mm to 0.55 mm;
3. Uniformity coefficient of smallest media should not be greater than 1.65;
4. The filter media should conform to AWWA/ANSI standards; and
5. Dual-media specifications:

	Range	Typical
Anthracite:		
Depth (mm)	300 – 600	450
Effective Size (mm)	0.8 – 2.0	1.2
Uniformity Coefficient	1.3 – 1.8	1.65
Silica Sand:		
Depth (mm)	150 – 300	300
Effective Size (mm)	0.45 – 0.55	0.5
Uniformity Coefficient	< 1.7	< 1.65

6. Multi-media specifications:

	Range	Typical
Anthracite:		
Depth (mm)	500 – 600	550
Effective Size (mm)	0.8 – 2.0	1.2
Uniformity Coefficient	1.3 – 1.8	1.65
Silica Sand:		
Depth (mm)	150 – 300	200
Effective Size (mm)	0.45 – 0.55	0.50
Uniformity Coefficient	< 1.7	1.65
Garnet:		
Depth (mm)	50 – 100	75
Effective Size (mm)	0.15 – 0.35	0.25
Uniformity Coefficient	< 1.7	< 1.65

7. Torpedo Sand:

	Range	Typical
Depth (mm)	75	75
Effective Size (mm)	0.8 – 2.0	1.2
Uniformity Coefficient	< 1.7	1.5

(Alberta; GLUMRB recommends both sand and anthracite have ES=0.45-0.55mm, UC=1.65; Alberta selected due to allowance of a range of media properties.

8. Granular activated carbon (GAC) as a single media may be considered for filtration only after the piloting requirements of Section 2.2.3.2 have been satisfied, and provided the design meets the following requirements:

    a) The media should meet the following specifications (*AWWA/ASCE*):

        Iodide Number: > 500 mg/g carbon
        Density: 0.25 g/cc
        Moisture Content: < 8% by wt.
        Ash Content: < 4% by wt.
        Effective Size: 1.2 – 1.6 mm
        Uniformity Coefficient: < 1.9
        Empty Bed Contact Time: 5 – 25 minutes

Depth: 0.3 – 1.2 m
Effective Size: 0.50 to 0.65 mm

b) There should be a means for periodic treatment of filter material for control of bacterial and other growth (typically utilizing an oxidant or disinfectant); and

c) Provisions should be made for replacement, or regeneration, of media.

9. Other media, including mixed-media (i.e., media not conforming to the above criteria), should be considered experimental in nature and should be subject to pilot testing as per the requirements of Section 2.2.3.2.

4.5.1.7 Filter Underdrains

Filter underdrains may either be gravel or proprietary designs (such as porous plate), unless otherwise approved. Manifold type underdrain systems should meet the following requirements, unless otherwise approved:

1. Gravel, when used as a supporting media, should consist of cleaned and washed, hard, rounded silica particles and should not include flat or elongated particles. The coarsest gravel should be 62 mm in size when the gravel rests directly on the strainer system, and must extend above the top of the perforated laterals. Gravel underdrain media should consist of a minimum of four (4) layers, unless otherwise approved, meeting the following requirements:

Size	Depth
62 mm – 38 mm	125 mm – 200 mm
38 mm – 19 mm	75 mm – 125 mm
19 mm – 12 mm	75 mm – 125 mm
12 mm – 5 mm	50 mm – 75 mm
5 mm – 2.5 mm	50 mm – 75 mm

2. Minimize headloss in the manifold and laterals;

3. Ensure an even distribution of backwash water and an even rate of filtration over the entire area of the filter;

4. Provide the ratio of the area of the final openings of the strainer system to the area of the filter at approximately 0.003 (*AWWA/ASCE recommends 0.0015 to 0.005, GLUMRB selected for consistency*);

5. Provide the total cross sectional area of the laterals at approximately 200% of the total area of the final openings (*AWWA/ASCE recommends 200 to 400%,*

GLUMRB selected for consistency);

6. Provide the cross sectional area of the manifold at approximately 150% to 200% of the total area of the laterals (*AWWA/ASCE recommends 150 to 300%, GLUMRB selected for consistency*); and

7. Lateral perforations without strainers should be directed downwards.

4.5.1.8 Surface Wash or Subsurface Wash

Surface or subsurface wash facilities should be provided, except for filters used exclusively for iron and manganese control, and should meet the following requirements:

1. Systems should be of a fixed nozzle or revolving type apparatus;

2. Water pressure should be minimum 310 kPa (45 psi);

3. A vacuum or siphon breaking device should be installed to prevent backsiphonage, if connected to the treated water system;

4. Rate of flow to be 4.9 m/hr for fixed nozzles and 1.2 m/hr for revolving arms; and

5. Air wash should be considered based on experimental and/or operating experience.

Surface wash systems can be replaced by air scour systems, provided that the requirements of Section 4.5.1.9 are satisfied.

4.5.1.9 Filter to Waste

Filter to waste connections should be provided for all filters and should be directed to the waste treatment and/or disposal system.

4.5.1.10 On-line Turbidity Monitoring

On-line continuous read turbidity meters should be provided for all filters, including filters used specifically for iron and manganese removal. The readout should be data-logged continuously and be connected to the SCADA system.

4.5.1.11 Filter Appurtenances

The following should be provided for all filters:

a) Influent and effluent sampling taps;

b) An indicating loss of head gauge;

c) An indicting rate of flow meter;

d) A rate controller which limits the rate of filtration to the maximum rate should be used;

e) Where used for surface water, provisions for filtering to waste with appropriate backflow prevention measures;

f) Wall sleeves providing access to the filter interior at several locations for sampling or pressure sensing;

g) A 50 to 62 mm pressure hose and storage rack at the operating floor for washing filter walls; and

h) Particle monitoring equipment is recommended for surface water plants.

4.5.1.12 Backwashing

Storage Requirements

Sufficient volume of water should be provided for backwashing all filters every 24 hours. An equivalent volume of equalization may be required for plants that store their backwash prior to treatment and/or ultimate disposal.

System Design

Backwashing systems should be designed to meet the following requirements:

1. Backwashing rates should be:
    a) sufficient to provide minimum 50% expansion of the filter bed;
    b) between 36 and 54 m/hr for systems not using air scour *(Alberta; GLUMRB suggests 37-50 m/hr);*
    c) between 12 and 18 m/hr for systems using air scour;
    d) 24 m/hr for full depth anthracite or GAC filters;

2. Backwashing duration should be:
    a) A minimum 15 minutes of backwash water for systems that do not use air scour*; and*
    b) A minimum 10 minutes of backwash water for systems that use air scour *(Alberta; GLUMRB suggests minimum 15 minutes under all circumstances;*

Alberta selected as air scour helps to reduce backwash time).

3. Air scour duration should be as specified in Section 4.5.1.11;

4. Backwash water should be filtered water, provided from the clearwell, backwash tanks, or the service watermain;

5. Backwash pumps should include a minimum of one (1) duty and one (1) stand-by pump;

6. A flow regulator and a flow meter should be provided on the main backwash header;

7. System should be designed such that rapid changes in backwash water flow rate do not occur; and

8. Backwash systems should be operator initiated, and automatic systems should be operator adjustable.

4.5.1.13 Air Scour

Air scour systems should meet the following requirements:

1. Air scour systems should be designed with an air scour airflow rate of 54 to 90 m/hr;

2. Air scour duration should be 3 to 5 minutes *(Alberta)*;

3. Air is to be introduced in the underdrain system;

4. Design should minimize loss of filter media;

5. Air scour should be followed by backwashing as per Section 4.5.1.10;

6. Air should be free of contamination;

7. Air distribution piping should be sufficient to prevent pipe collapse or bursting under maximum pressures;

8. Air delivery piping should not pass through the unfiltered water; and

9. Consideration should be given to maintenance and replacement of air delivery piping.

4.5.2 Rapid Rate Pressure Filtration

Pressure filtration is typically used in situations where an ion-selective media is used (e.g., iron and manganese removal systems), although it is also commonly used in small-scale applications for particle removal (as defined in Chapter 9). In any event, pressure filtration systems should not be used for filtration of surface water and should only be used for systems that do not require coagulation (due to the potential for floc breakup).

4.5.2.1 Rate of Filtration

Pressure filtration systems should be designed such that a minimum filtration rate of 7.2 m/hr is provided. Use of higher filtration rates will be subject to pilot testing requirements as specified in Section 2.2.3.2.

4.5.2.2 Additional Requirements

Pressure filtration systems **should meet the requirements specified in Section 4.5.1**, in addition to the following:

1. Loss of head gauges are to be provided on the inlet and outlet pipes of each filter;

2. An easily readable flow meter should be provided for each bank of units and a flow indicator should be provided on each individual unit;

3. Minimum sidewall height should be 1500 mm;

4. Backwash water troughs/collectors should be minimum 450 mm above media surface;

5. An adequate underdrain system capable of uniformly distributing a backwash water flow rate of 37 m/hr should be provided;

6. Backwash water flow indicators should be provided;

7. Air release valves on the highest points of each filter should be provided;

8. A manway should be provided on filters greater than 900 mm in diameter and handholes should be provided on filters less than 900 mm in diameter;

9. Cross-connection control measures should be provided; and

10. Manholes should be greater than 600 mm in diameter.

4.5.3 Direct Filtration

Rapid rate gravity filtration processes that do not use clarification should be considered "direct filtration". Direct filtration is to be used only for high quality surface water. The raw water should have the following characteristics:

Color	< 20 color units
Turbidity	< 5 NTU
Algae	< 2000 asu/ml
Iron	< 0.3 mg/L
Manganese	< 0.05 mg/L

4.5.3.1 Piloting and Approval Requirements

Where direct filtration is proposed, an engineering report should be submitted prior to conducting pilot studies.

This report should include a historical summary of the meteorological conditions and of raw water quality with special reference to fluctuations in quality, and possible sources of contamination. The report should also include a description of methods and work to be conducted during the piloting phase.

The following raw water quality data should be evaluated in the report:

a) Colour;

b) Turbidity;

c) Concentrations of microbiological contaminants of concern;

d) Temperature;

e) Total solids; and

f) General inorganic chemical characteristics.

After approval of the engineering report, a pilot study demonstration should be conducted and should meet the requirements of Section 2.2.3.2 and be to the satisfaction of the reviewing authority. In-plant demonstration studies may be appropriate where conventional treatment plants are converted to direct filtration plants.

The pilot study should be conducted over a sufficient period of time to experience all expected raw water conditions throughout the year. The study should emphasize, but not be limited to, the following:

a) Chemical mixing conditions including shear gradients and detention periods;

b) Chemical feed rates;
c) Use of various coagulants and coagulant aids;

d) Flocculation conditions;

e) Filtration rates;

f) Filter gradation, types of media and depth of media;

g) Filter breakthrough conditions; and

h) Impact of recycling backwash water.

The pilot scale system should be of a similar type and configuration to that proposed for the full-scale facility. Prior to developing plans and specifications, a final report including the engineer's design recommendations should be submitted to the reviewing authority for approval.

4.5.3.2 Pretreatment

The coagulation and flocculation processes should be designed as per the design criteria outlined in the pilot studies and as per Section 4.3. Direct filtration systems should also be designed such that a clarification process could be installed at a later date, should one be required.

4.5.3.3 General Design

Filters used for direct filtration should be dual-media or mixed-media rapid rate gravity filters and **should meet the requirements of Section 4.5.1**, unless otherwise noted. Pressure filtration should not be used.

Online turbidity monitoring should be provided for each filter. Coagulant concentration monitoring should also be performed routinely.

4.5.3.4 Rate of Filtration

Filtration rates should be determined during pilot testing but in no case should exceed those rates specified in Section 4.5.1.2.

4.5.4 Diatomaceous Earth Filtration

Diatomaceous earth (DE) filtration may be suitable for the filtration of surface waters with low turbidity and low bacterial contamination.

4.5.4.1 Piloting Requirements

DE filtration systems should not be constructed without undertaking pilot studies as per the requirements of Section 2.2.3.2.

4.5.4.2 General Design

Options for DE filtration include pressure and vacuum systems. Vacuum systems are generally preferred due to their ability to permit visual observations of the filter surface.

The assessment of the options should include factors such as performance, cost, reliability, and ease of operation.

4.5.4.3 Treated Water Storage

Treated water storage capacity in excess of normal requirements should be provided such that:

1. The filters can be operated at/or below the approved rates during all conditions; and

2. Continuity of service is ensured during adverse raw water conditions with by-passing the systems.

4.5.4.4 Number of Units and Redundancy

The number of units should be as specified in Section 4.5.1.3.

4.5.4.5 Pre-coat

A uniform pre-coat should be applied hydraulically to each septum by introducing slurry to the tank influent line and employing a filter-to-waste or recirculation system. DE in the amount of 0.49 to 0.98 kg/m^2 of filter area, or an amount sufficient to apply a 1.6 mm coating should be used with recirculation. When pre-coating is accomplished with a filter-to-waste system, 0.74 to 0.98 kg/m^2 of filter area is recommended.

4.5.4.6 Body Feed

A body feed system to apply additional amounts of DE slurry during the filter run should be provided, the rate of which should be determined during pilot testing. Continuous mixing of the body feed slurry should also be provided. Operation and maintenance can be simplified by providing access to feed system and slurry lines.

4.5.4.7 Filtration

DE filtration systems should meet the following requirements:

1. Filtration rates should be between 2.4 m/hr and 3.7 m/hr, and should be determined during pilot testing;
2. Headloss should not exceed 210 kPa (30 psi) for pressure DE systems, or a vacuum of -51 kPa (15 inches of mercury) for a vacuum DE system;
3. A recirculation or holding pump should be used to maintain differential pressure across the filter when the unit is not in operation in order to prevent the filter cake from dropping off of the filter elements;
4. A minimum recirculation rate of 0.24 m/hr should be provided;
5. The filter elements (or septum) should be capable of withstanding maximum pressure and velocity variations during filtration and backwash cycles, and should be spaced such that no less than 25 mm is provided between elements or between any element and a wall;
6. The filter influent should be designed to prevent scour of DE from the filter element;
7. A satisfactory method to thoroughly remove and dispose of the spent filter cake should be provided;
8. A continuous monitoring turbidimeter with recorder should be provided on the filter effluent for DE plants treating surface water; and
9. Particle monitoring equipment should also be provided.

4.5.4.8 Appurtenances

The following should be provided for every DE filter:

1. Sampling taps for raw and treated water as per Section 3.9.1;
2. Loss of head or differential pressure gauge;
3. Flow meter;

4. Flow regulator;

5. Evaluation of the need for body feed and recirculation; and

6. Filter to waste.

4.5.5 Slow Sand Filtration

Slow sand filtration refers to the process in which water is gravity filtered at very low rates through a sand bed in which a biologically active layer forms on the top of the media. This biologically active layer is commonly referred to as a *Schmutzdecke*.

4.5.5.1 Application

The use of these filters will only be suitable for a very small percentage of water supplies and prior engineering and pilot studies as specified in Section 2.2.3.2 should be undertaken to confirm the suitability of the process for the raw water quality.

Slow sand filtration should not be used when either the raw water colour or the raw water turbidity exceed 15 TCU or 10 NTU, respectively, on any given day. Extensive raw water quality and piloting data should be obtained and should cover a period of at least one year to capture all of the seasonal water quality fluctuations. Note that slow sand filtration will have difficulty meeting treated water turbidity requirements in place in most jurisdictions, making it's application limited.

4.5.5.2 Number and Redundancy

The number of units should be as specified in Section 4.5.1.3.

4.5.5.3 General Design

Slow sand filters should be designed to provide:

1. A cover;

2. Headroom to permit normal movement by operating personnel for scraping and sand removal operations;

3. Adequate access hatches and access ports for ventilation and handling of sand;

4. Filter to waste;

5. Overflow at the maximum water level; and

6. Protection from freezing.

4.5.5.4 Rate of Filtration

Filtration rates should range from 0.04 to 0.40 m/hr *(AWWARF; AWWA/ASCE recommends 0.09-0.24; Alberta recommends 0.1-0.4 m/hr; IRC manual indicates 0.04-0.08; GLMURB recommends 4.2-15 m/h, which appears to be in error; AWWRF selected as provides the most commonly reported range).* Filtration rates above this range will have to be adequately demonstrated through piloting studies as per Section 2.2.3.2.

4.5.5.5 Underdrains

The supporting gravel should be as per the requirements of Section 4.5.1.6, *Rapid Rate Gravity Filtration.*

Each filter unit should be equipped with a main drain and an adequate number evenly spaced (max. 1000 mm) laterals to collect the filtered water, with a maximum water velocity of 0.23 m/sec.

4.5.5.6 Filter Media

Filter media should be clean, washed silica sand meeting the following requirements:

1. Minimum initial sand depth of 750 mm to 1300 mm (should be replaced when sand depth reaches 475 to 500 mm) *(GLUMRB uses 750 mm; AWWA/ASCE suggests 460-890mm; Alberta recommends 1.0-1.3 m; therefore sand depths selected to incorporate entire range)*;

2. Effective size between 0.15 mm and 0.30 mm (*GLMURB recommends 0.15-0.3; Alberta recommends 0.2-0.3; AWWA/ASCE provides no recommendation; AWWARF recommends 0.2-0.3; IRC manual indicates 0.15-0.3; 0.15-0.30 selected to cover entire range*);

3. Uniformity coefficient be less than 2.5 (*GLMURB recommends <2.5; AWWA/ASCE provides no recommendation; AWWARF recommends <3; Alberta recommends 1.5-2.0; IRC suggests < 3-5; GLUMRB maximum 2.5 selected to ensure adequate porosity in the media*);

4. Reuse of sand to promote biological seeding should be done such that the old sand is placed on top of new sand; and

5. Influent piping should be a minimum of 0.3 m above the media to prevent

media scour during operation.

4.5.5.7 Water Depth and Headloss

Design water depth should be between 1800 mm and 2100 mm and the effluent piping design should ensure that the water level is maintained above the level of the filter sand *(AWWA/ASCE; GLMURB recommends 0.9 – 1.8 m; AWWA/ASCE selected to allow for headloss).*

Headloss should be between 0.1 m (i.e., clean bed) and 2.0 m (i.e., final bed). *(Alberta; AWWA/ASCE recommends maximum headloss of 1.5m; Alberta used because 2.0m allows for longer filter run times that may be possible at greater design water depths)*

4.5.5.8 Appurtenances

Each filter should be equipped with a headloss gauge and a flow metering device and an effluent pipe designed to maintain the water level above the top of the filter sand.

4.5.5.9 Scraping and Ripening

Slow sand filters should be scraped as required to ensure the regulatory requirements are consistently met. Slow sand filters should be allowed to ripen for a sufficient amount of time to ensure the regulatory requirements are consistently met. Filter to waste should be directed to the waste treatment and/or disposal system. Frequency of scraping will vary with sand depth and raw water quality and can be more accurately determined during piloting. Ripening duration should also be confirmed during pilot testing.

4.5.6 Biological Filtration

Biological filtration should refer to the filtration of a surface water, or a groundwater with iron, manganese or significant organic material, which includes the establishment and maintenance of biological activity within the filtration media.

It is important to note that biological activity within a filter can have adverse effects on turbidity and microbial pathogen removal, head loss development, filter run times and distribution system corrosion. However this can be overcome with regular and frequent backwashing cycles as described in section 4.5.1.10.

4.5.6.1 General Design

Design of biologically active filters should ensure that aerobic conditions are maintained at all times.

Biological filtration often includes the use of ozone as a pre-oxidant to break down organic matter into biodegradable organic matter. GAC media is often used to support denser biofilms.

Filters used in biological filtration should be designed as rapid rate gravity filters and should meet the requirements of Section 4.5.1, unless otherwise noted. Pressure filtration should not be used for biological filtration.

4.5.6.2 Piloting Requirements

Biological filtration systems should not be constructed without undertaking pilot studies as per the requirements of Section 2.2.3.2.

4.5.7 Membrane Filtration

Membrane systems are emerging as a very popular water treatment unit process due to their ability to provide excellent quality water under variable raw water conditions.

There are currently a wide variety of membrane processes available and as such, detailed standards and guidelines for each is beyond the scope of this document. However, some basic design criteria will be specified that should pertain to all membrane systems.

4.5.7.1 Applicable Processes

The following membrane systems have emerged as feasible for use in potable water systems and therefore should be considered for approval by the regulator:

1. Microfiltration (MF);

2. Ultrafiltration (UF);

3. Nanofiltration (NF); and

4. Reverse Osmosis (RO).

Membranes have generally been classified into the categories based on their approximate pore size ranges. These categories are as follows:

Microfiltration	> 0.1 μm pore size
Ultrafiltration	0.01 - 0.1 μm pore size
Nanofiltration	0.001 – 0.01 μm pore size
Reverse Osmosis	0.0001 μm um pore size

μm = micrometre = (1×10^{-6} metres = 1×10^{-3} millimetres)

Generally, only nanofiltration and reverse osmosis have small enough pore sizes to reject aqueous salts, resulting in demineralization.

Depending on the source water, pretreatment requirements for membrane treatment can be significant. Generally, the feed water should be very low in organic and inorganic colloidal substances, metal oxides (particularly iron and manganese), biological substances. In addition, most membranes will not tolerate high or low pH water and free chlorine.

4.5.7.2 Number and Redundancy

Since most membranes are modular in nature, redundancy should be provided such that the following conditions are satisfied:

1. A minimum of two trains are provided;
2. A minimum of one redundant feed/suction pump is provided; and
3. The design capacity of the facility can be met with a minimum of 25% of the modules out of service at the approved flux rates.

4.5.7.3 Piloting Requirements

Membrane filtration systems should not be constructed unless adequate water quality and operating data exist to confirm the suitability and efficacy of such processes for a particular water supply source. If such data does not exist, pilot testing should be conducted and should meet the requirements of Section 2.2.3.2.

4.5.7.4 Membrane Materials

The first step in designing a membrane treatment plant is the selection of the membrane material. Membranes can be made from either organic polymers or inorganic materials. Material selection depends on the type of membrane, quality of water and the desired finished water quality. Properties of various membrane materials are provided in Table 4.1.

Table 4.1: Properties of various membrane materials

Material	pH Range	Tolerance to Chlorine (mg/L)	Maximum Temperature (°C)
Cellulose Acetate	3 to 6	~ 1	50
Polyamide	2 to 12	< 0.1	80
Polysulfone	1 to 13	~ 100	80
Aluminum Oxide (ceramic)	0 to 14	> 100	> 100

The two most important organic polymeric materials include cellulose acetate and polyamide, with other membranes being made from polypropylene, polyethylene, aromatic polyamides, polysulfone and other polymers (Mallevialle et al., 1996). Membranes can be constructed in either asymmetric or symmetric configurations.

Inorganic membranes are typically made of glass, ceramics or carbon and are fabricated with composite layers of inorganic material having different porosity or granularity (AWWA 1998). Inorganic membranes resist compaction, high temperature, and extreme pH values and can operate under a broad range of temperatures. The major drawback of inorganic membranes is their high density and cost.

Membranes can consist of hydrophilic or hydrophobic materials (AWWA, 1992), which can have an effect on fouling. Hydrophobic materials are more prone to fouling because they adsorb organic matter to a greater degree relative to the hydrophilic materials. However hydrophobic membranes will also have a stronger affinity for removal of DBP precursor.

4.5.7.5 Membrane Configurations

Membrane systems consist of membrane elements or modules that are generally manufactured in two different configurations, hollow fiber and spiral. Microfiltration and ultrafiltration generally use the hollow fiber. This geometry does not require extensive pretreatment because the fibers can be periodically backwashed and the conditions of turbulent flow over the membrane improve the "scouring" of the membrane surface. The advantage to using hollow fiber membranes is that there is a lower pressure drop within a membrane module as compared to spiral therefore resulting in lower energy consumption.

Flow through a hollow fiber membrane can either be from the inner lumen to the outside (inside-out flow) or from the outside to the inside of the fibers (outside-in flow.) For inside-out flow configuration, a positive pressure is required to push the water through the membrane. With this method, particle fouling will occur on the inside of the fiber, which may decrease the efficiency of backwashing. With outside-in flow configuration, a negative pressure or suction is required to draw the water through the membrane.

4.5.7.6 Design Criteria

Membranes should be designed according to the general design criteria provided in Table 4.2

Table 4.2: Typical membrane system design criteria

Design Parameter	Microfiltration	Ultrafiltration	Nanofiltration	Reverse Osmosis
Flux rate (L/m^2/hr)	34-170	34-170	14-34	10-34

TMP[1] (kPa)	20-600	30-700	310-1,000	2,000-10,000
Recovery	90-98%	85-95%	60-75%	50-60%
Temperature range (°C)	0-35	0-35	0-35	20-35
Cleaning frequency (days)	14-90	14-90	14-180	30-360
Removal Rating	0.1-0.2μm	0.01-0.1μm	95-98% rej. Of Mg50$_4$	98-99.7% rej. Of Nacl

[1] Transmembrane Pressure

4.5.7.7 Integrity Testing

There should be a means to directly measure membrane integrity every 24 hours such as through a pressure-decay test, diffusive air test or water displacement test. Indirect integrity testing methods using water quality parameters such as turbidity, particle counts, DOC and/or conductivity should also be routinely performed and should be on-line where possible. In the absence of direct integrity testing for NF/RO membranes, molecular markers such as Rhodamine WT or dyes may be considered.

4.5.7.8 Redundancy

All membrane systems should have one redundant train (i.e., n + 1 design). For smaller membrane systems (i.e., >2000 L/min), it may be acceptable to provide an additional module only, or, to design the system for 25% additional capacity.

4.6 DISINFECTION

Barring system specific exceptions, disinfection shall be provided for all public potable water supplies. Chlorine is the preferred disinfecting agent as it has good disinfection capabilities, established modes of transport, storage and handling, is well researched, cost-effective and has a measurable residual. However, other disinfectants such as chloramines, ozone, chlorine dioxide, ultraviolet light (UV) or mixed oxidants may also be considered.

4.6.1 Chlorination

Chlorination can be accomplished using either gas/liquid chlorine or calcium/sodium hypochlorite.

4.6.1.1 Inactivation Requirements

The method of determining adequate disinfection for chlorination should be the *Ct* (i.e., *Ct* = free chlorine concentration in mg/L × disinfectant contact time in minutes) concept. Contact time should be measured as the amount of time from when the chlorine is injected until it reaches the point of use. This may include both the retention time in chlorine contact chambers as well as transmission mains. In chlorine contact chambers, this should be at the discharge of the chamber. In pipes, this should be at the first customer. Chlorine contact chambers and pipes should be considered as separate reactors. The disinfectant concentration used in *Ct* calculations should always be the concentration at the discharge of the reactor at the point of first use.

Due consideration should be given to contact time of the chlorine in water with relation to pH, ammonia, taste, temperature, microbiological quality and THM formation potential (THMfp).

All chlorine contact chambers should be designed to minimize short-circuiting and the T_{10} concept should be utilized. Use of the T_{10} concept should ensure that 90% of the water treated will be disinfected within the specified retention. Tracer studies may be required to determine the T_{10} value in some circumstances. In most cases, baffling factors may be used to determine the T_{10} value. The required retention time should be the theoretical retention time divided by an appropriate baffling factor. A general guide to baffling factors is provided in Table 4.3. Tracer studies may be required to determine a more accurate baffling factor in some circumstances:

Table 4.3: Baffling factors for CT calculations

Baffling Condition	T_{10}/T	BAFFLING DESCRIPTION
Unbaffled	0.1	No baffling, agitated basin, very low length-to-width ratio, high inlet and outlet velocities
Poor	0.3	Single or multiple unbaffled inlets and outlets, no baffles
Average	0.5	Baffled inlet or outlet with some intrabasin baffles
Superior	0.7	Perforated inlet baffle, serpentine or perforated intrabasin baffles, outlet weir or perforated launders
Perfect	1.0	Pipes or basins with very high length to width ratio, perforated inlet, outlet and intrabasin baffles

When determining the appropriate contact time, consideration should be given to the required log removals necessary to meet regulatory requirements. Consideration should also be given to possible log-removal credits offered through the treatment unit processes, if any.

The following general guidelines should be followed when performing *Ct* calculations:

a) Use peak hourly flow;

b) Determine the volume of each process unit in the disinfection system using the minimum water level expected at the maximum hourly flow;

c) Calculate the theoretical retention time;

d) Determine the baffling factor based on unit process baffling conditions or by tracer studies; and

e) Calculate T_{10} by multiplying theoretical retention time by baffling factor.

4.6.1.2 Inactivation Requirements

At plants treating surface water, provisions should be made for applying disinfectant to the raw water, clarified water (i.e., pre-filtration), filtered water (i.e., post-filtration) and to the water entering the distribution system. For systems supplying groundwater, provisions should be made for applying disinfectant to the incoming raw water and the water being fed to the distribution system.

Continuous feed of chlorine at locations upstream of the chlorine contact chamber has the potential to increase system THMs. Careful consideration should be given to potential THM increases when selecting disinfectants and processes that require pre-chlorination.

4.6.1.3 Residual Chlorine

Chlorination systems should be designed to provide a minimum free chlorine residual of 0.2 mg/L throughout the distribution system *(NSDEL states 0.2 mg/L; GLUMRB suggests 0.2-0.5 mg/L)*. Minimum combined chlorine residual, if applicable, should be 1.0 to 2.0 mg/L. Local authorities may define specific minimum acceptable chlorine residuals concentrations. This requirements will likely depend on pH, temperature, contact time, or any other characteristics of the water supply system. Maximum residuals in the system should not exceed 4.0 mg/L *(NSDEL)*.

4.6.1.4 Chlorination Equipment

Type

Solution feed gas chlorinators or hypochlorite feeders of the positive displacement type should be provided.

Capacity

The chlorinator capacity should be such that a free chlorine residual of 2.0 mg/L can be maintained in the water at a contact time of 30 minutes when maximum flow coincides with maximum chlorine demand, and a 0.2 mg/L residual can be maintained throughout the distribution system. The equipment should be designed such that it will provide an accurate chlorine feed over the entire dosing range.

Stand-by Equipment

Where chlorination is provided for the protection of public health, redundant stand-by equipment should be provided such that it can replace the largest unit. Spare parts should be made available to replace parts subject to wear or breakage. Accurate metering of emergency units should also be provided.

Automatic Switchover

Automatic switchover of chlorine cylinders should be provided to prevent inadequately disinfected water from entering the distribution system.

Automatic Proportioning

Automatic proportioning chlorinators should be provided where the rate of flow does not remain constant.

Eductor

Each eductor should be selected for the point of application with consideration given to the quantity of chlorine to be added, the maximum injector flow rate, the injector location pressure, the injector operating pressure, and the size of the chlorine solution piping. Gauges for measuring water pressure and vacuum at the inlet and outlet of each eductor should be provided.

Injector/Diffuser

The chlorine solution injector/diffuser should be compatible with the point of application to provide a rapid and thorough mix with the water being treated. Where chlorine is injected into pipes, injectors should extend to the center of the pipe.

Residual Monitoring Equipment

Continuous on-line monitoring of chlorine residuals should be provided at all locations where disinfected water enters the distribution system. Chlorine residual test equipment recognized in the latest edition of Standard Methods for the Examination of Water and Wastewater should be provided and should be capable of measuring disinfectant residuals to 0.1 mg/L. It is recommended that the DPD method that utilizes digital readout with a self-contained light source be used, as a minimum. Automatic chlorine residual recorders should also be provided at a location immediately prior to the location where the treated water enters the transmission or distribution system. Consideration should also be given to installing residual monitoring equipment at treated water storage reservoirs at the point where the stored water enters the distribution system.

Automatic Shut-Off Capability

In the absence of automatic redundant equipment (combined with stand-by power facilities), the ability to shut off the water supply system in the event of lower than required chlorine residuals should be provided. This is necessary to prevent inadequately disinfected water from entering the distribution system.

Chlorinator Piping

The chlorinator water supply piping should be designed to prevent contamination of the treated water supply by sources of questionable quality. At all facilities treating surface water, pre- and post-chlorination systems should be independent to prevent possible cross-contamination with the contents of the clearwell. The water supply to each eductor should have a separate shut-off valve and master shut-off valves will not be permitted.

The pipes carrying elemental liquid or dry gaseous chlorine under pressure should be Schedule 80 seamless steel tubing or another material approved by the Chlorine Institute (note that PVC is not recommended). Rubber, PVC, polyethylene (PE) or other materials approved by the Chlorine Institute should be used for chlorine solution pipe and fittings (nylon materials is not recommended for any part of the chlorine solution piping system). Efforts should also be taken to minimize the length of pipe used to carry chlorine gas, liquid or concentrate (see Sections 3.6.2.11 and 3.6.3.2).

Housing

Adequate housing should be provided for chlorination equipment and chlorine storage (see Chapter 3).

4.6.1.5 General Guidelines

In addition to the requirements of Section 3.6.3.2, the following should be provided for all disinfection systems that use chlorination *(NSDEL)*:

a) Weigh scales constructed from corrosion resistant material and located remote from sources of moisture;

b) Chlorine leak detection equipment as per Chapter 3; and

c) Consideration should be given to chlorine gas scrubbers in highly populated areas.

Gas chlorination system design should take into consideration the following items *(NSDEL)*:

a) Chlorine cylinders stored separately and adequately secured so as to prevent damage to the cylinders;

b) Chlorine cylinders stored away from flammable material, heating/ventilation units, elevator shafts or uneven surfaces;

c) Temperature in the chlorination room and chlorine storage room should be the same to avoid condensation or evaporation in the piping conveying gas;

d) The chlorine gas conveyance piping should slope upwards towards the chlorinators to allow condensation to drain back to the chlorine cylinders;

e) The chlorine gas conveyance piping should not be located on an outside wall or any location where low temperatures may be encountered;

f) It is recommended that a strainer be installed on the waterline to the injector to prevent any possible grit or foreign material from entering and blocking the injector. Provision for flushing the screen is recommended and should precede the booster pump;

g) Tonne cylinders should be moved using an approved lifting mechanism; and

h) Chlorine institute emergency kit A and B should be provided.

4.6.2 Alternate Disinfectants

There are many types of disinfectants in addition to chlorine that have the potential to be used in potable water treatment applications. However, provisions of standards and guidelines for all of these is beyond the scope of this manual. Rather, a few of the more common alternate disinfectants will be identified and some general guidelines provided.

4.6.2.1 Types of Alternate Disinfectants

The following alternate disinfection processes should be given consideration by the reviewing Authority:

1. Chloramination;
2. Ozonation;
3. Chlorine Dioxide Addition;
4. Ultraviolet Disinfection; and
5. Mixed Oxidant Disinfection.

Consultation with the reviewing authority for specific requirements is recommended prior to proposing or proceeding with design using alternate disinfectants.

4.6.2.2 Process Descriptions

Chloramination

Chloramines are a weak disinfectant for *Giardia lamblia* and virus reduction and require long contact times for adequate disinfection. However, it does have a long-lasting residual and forms lower concentration of THMs in comparison to free chlorine. Therefore, chloramines may be best suited as a stable distribution system disinfectant.

When using chloramines, consideration should be given to the ammonia residuals in the finished water. Amounts fed in excess of the stoichiometric amount should be minimized to inhibit growth of nitrifying bacteria.

Ozonation

Ozone (O_3) is a very effective disinfectant for both *Giardia lamblia* and viruses, and is also used for taste and odour control. There are however, by-products of ozonation, which are regulated in some jurisdictions. Ozone does not provide a disinfectant residual and therefore, should only be used in conjunction with chlorine or chloramines. Ozone systems should include provisions for leak detection and alarms as well as an ozone off-gas destruction system.

Chlorine Dioxide

Chlorine dioxide is a strong disinfectant and does not tend to form THMs however, neither does it have a persistent residual. Chlorine dioxide residuals should be less than 0.3 mg/L under typical conditions and in no case should exceed 0.5 mg/L *(Alberta; AWWA/ASCE/USEPA all recommend a maximum dosage of 1.0 mg/L; Alberta selected for safety).* Chlorine dioxide is formed by the mixing of chlorine with sodium chlorite, which forms an explosive gas and as such, advanced leak detection, explosion proof measures and special safety precautions should be provided. Chlorite is a by-product of chlorine dioxide and should not be greater than 0.8 mg/L leaving the water treatment plant.

Ultraviolet Disinfection

Ultraviolet (UV) disinfection is the process by where UV light is applied to the water to be treated, which results in the inactivation of microbiological contaminants due to the mutagenic properties of the UV radiation. UV systems may provide relatively high inactivations of *Giardia, Cryptosporidium* and viruses, while not forming THMs. UV systems do not however provide a residual and as such, a secondary disinfectant such as chlorine should be provided.

The design of UV systems for potable water treatment should consider the following:

a) Be based on the lowest transmittance of the supply and should provide microbiological inactivation consistent with regulatory requirements;

b) Provide a minimum of two (s) units (1 duty and 1 stand-by) or a minimum of 50% redundancy (2 duty and 1 stand-by);

c) Be based on peak flow rates of the system at the point of disinfection;

d) Both low pressure-high output (LPHO) and medium pressure (MP) design configurations;

e) The reduction equivalent dosages (RED) in Table 4.4 should be used, unless a lower RED has been demonstrated through on-site validation testing as per the Draft USEPA UVDGM (June, 2003);

Table 4.4: RED Targets for 3-log Reductions (USEPA Draft UVDGM, June 2003)

Microorganism	LPHO	MP
Giardia	34 mJ/cm^2	40 mJ/cm^2
Cryptosporidium	36 mJ/cm^2	42 mJ/cm^2
Viruses	199 mJ/cm^2	231 mJ/cm^2

f) The requirements for start-up and cool-down of reactors;

g) Pretreatment requirements for reduction of turbidity, suspended solids and colour prior to UV disinfection;

h) Confirmation of UV reactor validation to achieve required pathogen inactivation;

i) The provision of continuous UVT monitoring with alarms, SCADA control, and automatic switchover to the stand-by UV module in the event of low UV transmittance;

j) The quality of the power supply and provision of stand-by power, automatic shut-off capability or alternate disinfection to prevent inadequately disinfected water from entering the distribution system;

k) Lamp aging and fouling potential;

l) Reactor hydrodynamics to ensure uniform UV dose distribution throughout the reactor;

m) Facility hydraulics to ensure even flow distribution through parallel reactors, including ten (10) pipe diameters upstream and five (5) pipe diameters downstream of the reactor;

n) Headloss requirements;

o) Cooling water requirements; and

p) Reactor isolation and lamp breakage response plans.

Mixed Oxidants

Mixed oxidants are proprietary oxidants that are formed by a combination of disinfectants specifically tailored to the treatment objectives and will require evaluation of their appropriateness on an individual basis. Information concerning pathogen inactivation will need to be demonstrated by the manufacturer and potential disinfectant by-products should be disclosed.

4.6.2.3 Contact Time

Alternate disinfectants should meet either the *Ct* requirements of Section 4.6.1.1, or, an approved equivalent disinfection ability such as the required microbiological removal requirements as per regulatory requirements (e.g., UV disinfection).

4.6.2.4 Disinfectant Residual

Regardless of the primary disinfectant used, free chlorine residuals should be provided consistent with Section 4.6.1.3. Should the primary disinfectant not be capable of providing the required chlorine residuals, then a secondary chlorination system should also be provided, consistent with the requirements of Section 4.6.1.

4.6.2.5 Piloting Requirements

Alternate disinfection systems should not be constructed unless adequate water quality and operating data exist to confirm the suitability and efficacy of such processes for a particular water supply source. If such data does not exist, pilot testing should be conducted and should meet the requirements of Section 2.2.3.2.

4.7 SOFTENING

The softening process selected should be based on the mineral qualities of the raw water and the desired finished water quality.

4.7.1 Lime or Lime-Soda Processes

Lime or lime-soda softening process should meet the following criteria:

1. Design of coagulation and clarification facilities should be as outlined in Section 4.3;

2. When split treatment is used, the by-pass should be designed to accommodate the total plant flow, and an accurate means of measuring and splitting flow should be provided;

3. Determinations should be made for the carbon dioxide content of the raw water to determine if removal by aeration is feasible;

4. Lime and recycled sludge should be introduced into the rapid mix basins;

5. Stabilization of the water softened by the lime or lime-soda process should be provided;

6. Mechanical sludge removal equipment should be provided in the sedimentation basins;

7. Provisions should be included for proper disposal of softening sludge;

8. The use of excess lime should not be considered an acceptable substitute for disinfection; and

9. Manual plant start-up should be provided after a plant shut-down.

4.7.2 Cation Exchange Processes

Cation exchange processes for removal of hardness should meet the following requirements:

1. Pre-treatment for iron or manganese should be provided when the combined concentration is 1.0 mg/L or greater;

2. Water having a turbidity greater than 5.0 NTU should not be applied to a cation exchange softener;
3. The units may be of the pressure type and of either upflow or downflow design;
4. Automatic regeneration based on volume of water softened should be provided;
5. Manual overrides should be provided;
6. The design capacity for removal of hardness should not exceed 46 kg/m^3 when resin is generated with 0.14 kg of salt per kilogram of hardness removed;
7. The depth of the cation exchange resin should not exceed 1000 mm;
8. The rate of softening should not exceed 17 m/hr;
9. Backwash rates range from 14-20 m/hr and the backwash water collector should be minimum 600 mm above the resin on downflow systems;
10. Underdrain systems and supporting gravel should conform to Section 4.5.1.6;
11. Facilities should be included for even distribution of brine over the entire surface of both upflow and downflow units;
12. Backwash, rinse and air relief pipes should be installed in such a manner as to prevent possibility of back-siphonage;
13. A metered by-pass should be provided around the softening units with an automatic proportioning or regulating device;
14. Silica gel resins should not be used for waters having a pH above 8.4 or containing less than 6 mg/L silica or when iron is present;
15. When the applied water contains a chlorine residual, the cation exchange resin should be resistant to chlorine (phenolic resin should not be used);
16. Sampling taps are to be provided on the softener influent, effluent, blended water, and brine tank discharge piping;

17. Brine storage tanks:
    - i. Salt dissolving or brine storage tanks should be covered and should be corrosion resistant;
    - ii. The make-up water inlet should be protected from back-siphonage and the filling pipes should be located above the brine level in the tank;
    - iii. Automatic declining level control system should be provided on the make-up water line;
    - iv. Wet salt storage basins should be equipped with manholes or hatchways for access and direct dumping of salt from a truck or railcar (openings should be watertight);
    - v. Overflows, where provided, should be protected with corrosion resistant screens, should have a turned down bend at the termination point and should have a free-fall discharge or a self-closing flap valve;
    - vi. Two wet salt storage tanks designed to operate independently should be provided;
    - vii. Salt should be placed on graduated layers of gravel placed over a brine collection system.

18. Total salt storage should have the greater of 1.5 truckloads of salt or be sufficient for 30 days of storage;

19. An eductor may be used to transfer brine from the brine tank to the softeners or, alternatively, if a pump is used a brine measuring tank should be provided;

20. A suitable means of water stabilization should be provided;

21. Suitable disposal should be provided for brine waste;

22. Piping should be resistant to the aggressiveness of salt (plastic and red brass are acceptable however, steel and concrete should be adequately lined);

23. Bagged and dry bulk salt storage should be enclosed and be separate from other operating areas; and

24. Test equipment for alkalinity, total hardness, carbon dioxide content and pH should be provided.

4.8 AERATION

Aeration may be used for any one of the following reasons:

1. To help remove taste and odour;
2. To removal volatile organic matter;
3. To remove carbon dioxide; and
4. To assist in iron and/or manganese oxidation.

Aeration is typically provided by the following methods, depending on treatment objectives:

1. Natural draft aeration;
2. Forced or induced draft aeration; and
3. Packed tower aeration.

4.8.1 Natural Draft Aeration

Design should provide:

1. Perforations to the distribution pan 5 to 12 mm in diameter, spaced 25 to 75 mm on centers to maintain a 150 mm water depth;
2. For distribution of water uniformly over the top tray;
3. Discharge through a series of three or more trays with separation of trays not less than 300 mm;
4. A loading rate of 2.5 to 1.5 m/hr;
5. Trays with slotted, heavy wire mesh (12 mm openings) or perforated bottoms;
6. Construction of durable material resistant to aggressiveness of water and dissolved gases;
7. Protection from loss of spray water by wind using enclosures with louvers sloped to the inside at an angle of 45 degrees; and
8. Protection from insects by 24 mesh screen.

4.8.2 Forced or Induced Draft Aeration

Devices should be designed to:

1. Include a blower with a weatherproof motor in a tight housing and screened enclosure;
2. Ensure adequate countercurrent of air through the aerator column;
3. Exhaust air directly to the outside atmosphere;
4. Include a down turned and 24 mesh screened air inlet/outlet;
5. Introduce air into the column as free from fumes, dust, and dirt as possible;
6. Be such that sections of the aerator can be easily removed for maintenance of the interior or installed in a separate aerator room;
7. Provide a loading rate of 2.5 to 12.5 m/hr;
8. Ensure that the water outlet is adequately sealed to prevent unwarranted loss of air;
9. Discharge through a series of five or more trays not less than 150 mm;
10. Provide water distribution uniformly over the tray; and
11. Be resistant to corrosion.

4.8.3 Spray Aeration

Design should provide:

1. A hydraulic head of between 1.5 and 7.6 metres;
2. Nozzles, with the size, number and spacing of the nozzles being dependent on the flow rate, space and amount of head available;
3. Nozzle diameters in the range of 25 to 38 mm;
4. An enclosed basin to contain the spray; and
5. 24 mesh screen for openings for ventilation.

4.8.4 Pressure Aeration

Pressure aeration for oxidation purposes should be subject to pilot testing as per the requirements of Section 2.2.3.2. Pressure aeration should not be considered for the removal of dissolved gases. Filters following pressure aeration should have adequate exhaust devices for release of air.

Pressure aeration systems should be designed to:

1. Give thorough mixing of compressed air with the water being treated; and
2. Provide screened and filtered air, free of dust, fumes, and dirt.

4.8.5 Packed Tower Aeration

Packed tower aeration (PTA) is also commonly known as "air stripping" and is generally used for removing volatile organic chemicals, trihalomethanes, carbon dioxide and radon.

4.8.5.1 Piloting Requirements

PTA is generally only satisfactory for removing compounds with a Henry's Constant greater than 100 (atm mol/mol) and is not normally feasible for compounds with a Henry's Constant less than 10. For values between 10 and 100, pilot testing should be conducted and should meet the requirements of Section 2.2.3.2. Values for Henry's constant should be discussed with the reviewing authority prior to developing plans and specifications.

In addition to those requirements in Section 2.2.3.2, pilot testing should evaluate a variety of loading rates and air:water ratios at the peak contaminant concentrations. Special consideration should be given to removal efficiencies when multiple contaminations occur.

Piloting may not be required where sufficient operating data adequately demonstrates the feasibility of the process for a specific contaminant. Such will be evaluated on a case-by-case basis by the reviewing Authority.

4.8.5.2 Process Design

Process design for PTA requires the determination of Henry's Constant for contaminant, the mass transfer coefficient, the air pressure drop and the stripping factor. The design should consider the height and diameter of the unit, the air to water ratio, the packing depth and the surface loading rate. The tower should also be designed to meet the following:

1. Contaminants should be reduced to below the Regulatory requirement and to the lowest practical level;

2. The ratio of column diameter to packing diameter should be minimum 10:1;
3. The volumetric air to water ratio at peak flow should be between 25:1 and 80:1;
4. The design should consider potential fouling due to calcium carbonate and iron precipitation from bacterial regrowth (a pre-treatment system may be required); and
5. The effects of temperature should also be considered.

4.8.5.3 Materials of Construction

The tower and the packing material should be resistant to the aggressiveness of the water and should be suitable for contact with potable water.

4.8.5.4 Water Flow System

The water flow system should be designed to meet the following requirements:

1. Water should be distributed uniformly at the top of the tower using spray nozzles or orifice-type diffusers with one injection point every 190 cm^2 of tower cross-sectional area;
2. A mist eliminator should be provided;
3. A side wiper redistribution ring should be provided at least every three (3) metres in order to prevent water channeling and short circuiting along the tower wall;
4. Sample taps should be provided on the influent and effluent piping;
5. The effluent sump, if provided, should have easy access and be equipped with a drain valve, which should not be connected to any storm or sanitary sewer;
6. A blow-off line should be provided in the effluent piping to allow discharge of cleaning chemicals and water;
7. The design should prevent freezing of the influent riser and effluent piping when the unit is not operational (if buried, the piping should be maintained under positive pressure);
8. The water flow to each tower should be metered;

9. An overflow should be provided with proper drainage;

10. Means of preventing flooding of the air blower should be provided; and

11. The influent pipe should be supported separately from the tower itself.

4.8.5.5 Air Flow System

The air flow system design should:

1. Ensure the air inlet to the blower is turned down and covered with a 24 mesh screen (it is also recommended that a 4 mesh screen be provided over the air inlet);

2. Have an air inlet in a protected location;

3. Provide air flow metering on the influent air piping;

4. Provide a positive air flow sensing device and a pressure gauge on the air influent piping (the air flow sensing device should be part of an automatic control system that will turn off the influent water if air flow is not detected); and

5. A backup blower motor or stand-by blower should be provided.

4.8.5.6 Other

Other measures that should be provided include:

1. A sufficient number of access ports with a minimum diameter of 600 mm to facilitate inspection, media replacement, media cleaning and maintenance of the interior;

2. A method of cleaning the packing material should be provided;

3. Tower effluent collection and pumping wells should be constructed to clearwell standards;

4. Provisions for future plant expansion and tower height increase;

5. An acceptable alternative supply should be available during periods of maintenance and operations interruption;

6. No by-pass should be provided;
7. Disinfection application points should be provided both upstream and downstream of the tower;
8. Adequate packing support should be provided to allow free flow of water and prevent deformation of packing material;
9. Stand-by power should be provided as per Chapter 3 for blower and disinfectant feeding equipment;
10. Security measures should be provided as per Chapter 3;
11. An access ladder and safety cage should be provided for inspection of the exhaust port and demister;
12. Electrical interconnection between blower, well pump and disinfectant feeder should be provided;
13. Adequate foundation;
14. Check with local regulatory authorities to determine if permits are required for the air discharge; and
15. Noise control should be considered for PTA systems located in residential areas.

4.8.6 Other Methods of Aeration

Other methods of aeration such as spraying, diffused air, cascades and mechanical aeration may be considered and may be subject to pilot testing requirements.

4.8.7 Protection of Aerators

All aerators, except those discharging to lime softening or clarification plants, should be protected from contamination by wind, debris, birds, insects, rainfall and water draining off the exterior of the aerator.

4.8.8 Disinfection

Disinfection should meet the requirements of Section 4.6

4.8.9 By-Pass

A by-pass should be provided for all aeration units except those installed to comply with maximum contaminant levels.

4.8.10 Corrosion Control

The aggressiveness of the water should be determined and corrected by additional treatment, if necessary.

4.8.11 Quality Control

Equipment should be provided to test for DO, pH and temperature. Equipment to test for iron, manganese and carbon dioxide should be considered.

4.9 IRON AND MANGANESE CONTROL

Iron and manganese control, as used herein, refers solely to those treatment processes designed specifically for iron and manganese removal and the treatment process used should be dependent on the raw water quality. Treatment objectives in addition to iron and manganese may, to some degree, dictate the ultimate process used. In any event, the treatment process selected should be capable of removing not only iron and manganese but also, any other contaminants that may be present at or below the regulatory requirements.

4.9.1 Removal by Oxidation, Detention and Filtration

Oxidation may be by aeration, as indicated in Section 4.8, or by chemical oxidation with chlorine, potassium permanganate, ozone, or chlorine dioxide.

A minimum detention time of 30 minutes should be provided following aeration, unless indicated otherwise through pilot testing (see Section 2.2.3.2). The detention basin may be designed as a holding tank without provisions for sludge removal with sufficient baffling to prevent short-circuiting. Removal with oxidation by potassium permanganate, chlorine and chlorine dioxide is "rapid" and the design of detention basins should provide minimum five (5) minutes of contact time.

Sedimentation basins should be provided when treating for high iron and/or manganese content, or where chemical coagulation is used. Provisions for sludge removal should be made. Sedimentation basin design should meet the requirements of Section 4.4.1. Filters should meet the requirements of Section 4.5.

4.9.2 Removal by Lime-Soda Softening

Removal of iron and/or manganese by the lime-soda softening process should meet the requirements of Section 4.7.

4.9.3 Removal by Manganese Coated Media Filtration

Removal of iron and manganese by contact adsorption using pre-coated filter media is the preferred method of treating iron and/or manganese at concentration up to 5 mg/L and 1 mg/L, respectively.

4.9.3.1 Oxidant Addition

An oxidant, typically potassium permanganate, is added to the raw water to oxidize soluble iron and manganese. Dosages should be selected that will take into consideration all oxidant demands including the contaminants to be removed as well as DOC, ammonia, and hydrogen sulfide, among others. Other oxidizing agents such as chlorine or aeration may be used to reduce the required permanganate dosage, however, their impacts on THM formation should be determined. Pilot studies as per the requirements of Section 2.2.3.2 may be required to confirm actual required dosages. Provisions should be made to apply the permanganate as far in advance of the filter as possible to maximize the contact time prior to the oxidized water reaching the filters (this may require a small contact tank in some cases to ensure adequate contact time). This process is highly pH dependant. Elevated pH levels may be required for adequate removals particularly for manganese. The optimum operational pH level will be site specific.

4.9.3.2 Media

Typically, manganese greensand will be used for the removal of iron and manganese. Iron removal systems should be dual-media systems incorporating a layer of anthracite a minimum of 150 mm thick.

4.9.3.3 Design

Iron and manganese removal systems should be designed as outlined in Table 4.5 *(Alberta)*:

Table 4.5: Iron and manganese removal system design criteria

	Iron Removal	Manganese Removal
Regeneration of media	Continuous	Intermittent
Bed type	Dual media	Single
Anthracite	375 – 450 mm	None
Manganese greensand	450 – 600 mm	> 750 mm
PH	6.2 – 8.5	7.0 – 8.5
Filtration rate	4.0 – 7.2 m/hr	4.0 – 7.2 m/hr
Headloss	1.5 m maximum	1.5 m maximum
Backwash	40% bed expansion	40% bed expansion

Backwash rates should be 20-24 m/hr for manganese greensand and 37-24 m/hr for manganese coated media. Air scour should also be provided as per Section 4.5.1.9. Iron and manganese are often present together. Ensuring adequate removals of both may require bench or pilot-scale studies to establish the optimum oxidant, pH, and filter media composition.

4.9.3.4 Sample Taps

Sample taps should be provided at the following locations:

1. Prior to the application point of potassium permanganate;

2. Immediately before filtration;

3. At the individual filter effluents; and
4. At points between the anthracite media and the manganese coated media.

4.9.4 Proprietary Media

There are a number of proprietary iron and manganese removal media currently available. Their discussion is beyond the scope of this manual. These proprietary media may be satisfactory in many circumstances. If, in the opinion of the regulator, sufficient data is not present to establish the feasibility of the process, pilot studies may be required.

4.9.5 Removal by Ion Exchange

Ion exchange should not be used for water containing greater than 0.3 mg/L of iron or above and/or manganese, or where the raw or backwash water contains dissolved oxygen.

4.9.6 Treatment by Sequestration

4.9.6.1 Polyphosphates Sequestration

This process should not be used for water containing 1.0 mg/L of iron or above and/or manganese. The total phosphate applied should not exceed 10 mg/L as PO_4. Phosphate addition should not adversely affect chlorine residuals or corrosion control in the distribution system.

Stock phosphate solution should be kept covered and disinfected by carrying approximately 10 mg/L free chlorine residual. Phosphate solutions having a pH of 2.0 or less may be exempt from this requirement.

Polyphosphates should not be applied ahead of iron and/or manganese removal treatment. The point of application should be prior to any aeration, oxidation or disinfection if no iron or manganese removal treatment is provided.

4.9.6.2 Sodium Silicates Sequestration

Sodium silicate sequestration of iron and manganese may be appropriate for water containing up to 2 mg/L of iron and/manganese and is also only suitable for groundwater supplies prior to air contact. On-site pilot testing should be conducted for sodium silicate sequestration as per Section 2.2.3.2. Rapid oxidation of iron and/or manganese by chlorine or chlorine dioxide should accompany or precede sodium silicate addition by no greater than 15 seconds.

Chlorine residuals in the distribution system should not be adversely affected. The amount of silicate added should be limited to 20 mg/L as SiO_2, and the amount of silicate added and natural silicate should not exceed 60 mg/L as SiO_2. Sodium silicate should not be applied before iron and manganese removal processes.

4.9.7 Sampling Taps

Sampling taps should be provided as per Chapter 3.

4.9.8 Testing

Testing equipment should be provided for all plants and should meet the requirements of Chapter 3. The equipment should have the capacity to measure iron and manganese to minimum concentrations of 0.1 mg/L and 0.05 mg/L, respectively. Where polyphosphate sequestration is practiced, phosphate testing equipment should be provided.

4.10 FLUORIDATION

4.10.1 Naturally Occurring Fluoride

Where fluoride is naturally occurring and above the GCDWQ or regulatory requirements, fluoride should be removed by an acceptable means to less than the required limit. Such methods might include ion exchange, reverse osmosis or proprietary technologies (refer to appropriate sections in the manual for fluoride removal process design guidelines).

4.10.2 Artificial Fluoridation

Where artificial fluoridation is provided, a dosage of 0.8 mg/L of fluoride is recommended and should not exceed 1.0 mg/L. Sodium fluoride, sodium silicofluoride and fluorosilic acid may be used for fluoridation and should meet the applicable AWWA and NSF standards. Any other compounds used for fluoridation will be considered on an individual basis.

4.10.2.1 Fluoride Compound Storage

Fluoride chemicals should be isolated from other chemicals to prevent contamination. Compounds should be stored in covered or unopened shipping containers within a building. Unsealed storage units for fluorosilic acid should be vented to the atmosphere at an exterior location. Bags, fiber drums and steel drums should be stored on pallets.

4.10.2.2 Chemical Feed Equipment and Methods

In addition to the requirements in Chapter 3, fluoride systems should contain the following:

1. Scales, loss-of-weight recorder or liquid level indicators should be provided, accurate to within 5% of the average daily change in readings;
2. Feeders should be accurate to within 5% of any desired feed rate;
3. Fluoride hoppers should be designed to hold a 24 hour supply of fluoride;
4. Fluoride compound should not be added prior to lime-soda softening or ion exchange softening processes;
5. The application point of fluorosilic acid, if in a pipe, should be in the lower half of the pipe;
6. A fluoride solution should be applied by a positive displacement pump having a stroke rate not less than 20 strokes per minute;
7. A day tank capable of holding a 24 hour supply of fluoride should be provided;
8. A spring-opposed or solenoid operated diaphragm-type anti-siphon device should be provided for all fluoride feed lines and dilution water lines;
9. The dilution water pipe should terminate at least two pipe diameters above the solution tank;
10. Water used for sodium fluoride dissolution should be softened if hardness exceeds 75 mg/L (as $CaCO_3$);
11. Fluoride solutions should be injected at a point of continuous positive pressure or a suitable air gap provided;
12. The electrical outlet used for the fluoride feed pump should have a non-standard receptacle and should be interconnected with the well or service pump;
13. Saturators should be of the upflow type and be provided with a meter and backflow protection on the make-up water pipe;

14. All fluoridated water should be metered;
15. Floor drains should not be provided, unless discharged to an appropriate treatment system or holding facility;
16. Construction should be of corrosion resistant material;
17. Should provide dripping tap at each pipe drain;
18. Locate only basic essential electrical controls in the fluoride room;
19. Use explosion proof motors and electrical components;
20. Install conduits such that servicing is easily facilitated;
21. All light and fan switches should not be located within the fluoride room;
22. Feeders should be provided with anti-siphon devices on the discharge;
23. Alarm signals are recommended, where appropriate; and
24. Flow proportioning or a compound loop residual control system is recommended.

4.10.2.3 Secondary Controls

Secondary control systems for fluoride chemical feed devices should be provided as a means of reducing the possibility of overfeeding. These devices may include flow or pressure switches, or other such devices.

4.10.2.4 Protective Equipment

Personal protective equipment as outlined in Chapter 3 should be provided for operators handling fluoride compounds. Deluge showers and eye wash stations should be provided at all fluorosilic acid installations.

4.10.2.5 Dust Control

Provision should be made for the transfer of dry fluoride compounds from shipping containers to storage bins or hoppers in such a way as to minimize the quantity of fluoride dust which may result. The enclosure should be provided with an exhaust fan and dust filter which place the hopper under a negative pressure. Air exhausted from the fluoride handling equipment should pass through a dust filter and discharge to the exterior of the facility, away from any air intakes.

Provision should be made for disposing of empty bags, drums or barrels in a manner which will minimize dust generation. A floor drain should be provided for wash down of floors in the fluoride area.

4.10.2.6 Testing Equipment

Equipment should be provided for measuring fluoride in the raw and treated water.

4.11 STABILIZATION AND CORROSION CONTROL

Water that is unstable/corrosive due to natural and/or subsequent treatment processes should be stabilized.

4.11.1 Carbon Dioxide Addition

Recarbonation basins should provide:

1. A total minimum detention time of 20 minutes;
2. Two compartments, with a depth that will provide a diffuser submergence greater than 2.3 m but not greater that the submergence recommended by the manufacturer, as follows:
   i. A mixing compartment having a minimum detention time of 3 minutes
   ii. A reaction compartment
3. Plants generating carbon dioxide from combustion should have open top recarbonation tanks in order to dissipate carbon monoxide gas;
4. Where liquid carbon dioxide is used, adequate precautions should be taken to prevent carbon dioxide from entering the plant during the recarbonation process; and
5. Provisions should be made for draining the recarbonation basin and for removing sludge.

4.11.2 Acid Addition

Feed equipment should conform to Chapter 3. Operator safety precautions should be followed as outlined in Chapter 3. Piping materials should be of a type suitable for the chemical being fed.

4.11.3 Phosphates

The feeding of organic phosphates may be used for sequestering calcium in lime-softened water, corrosion control, and in conjunction with alkali feed following ion exchange softening. Phosphate addition should meet the following requirements:

1. Feed equipment should conform to Chapter 3;
2. Stock phosphate solution should be kept covered and disinfected by maintaining approximately 10 mg/L chlorine residual (phosphate solutions having a pH of 2 or less may be exempt from this requirement); and
3. Adequate chlorine residuals should be maintained in the distribution system.

Note that when using phosphates for corrosion control, the Langlier Saturation Index is no longer applicable for determination of corrosion protection potential.

4.11.4 Split Treatment

Under some circumstances, a lime-softening water treatment plant can be designed using "split treatment" in which raw water is blended with lime-softened water to partially stabilize the water prior to secondary clarification and filtration. Treatment plants that utilize "split treatment" should also contain facilities for further stabilization by other means.

4.11.5 Alkali Addition

Water with low alkalinity should be stabilized. Perhaps the most common method of water stabilization is alkali addition. Alkali addition involves the addition of a base to raise the pH of the water within the range stipulated by the Regulatory requirements or to a non-corrosive state. The most common chemicals used for this purpose include lime, sodium hydroxide and soda ash (others may be possible and will be subject to approval by the reviewing Authority).

Stabilization by alkali addition should provide a Langlier Saturation Index (LSI) of 0 (or slightly positive) in the water to be treated. Water with a negative LSI is typically considered to be corrosive while water with a positive LSI is typically considered to be scale forming and is likely to precipitate a protective calcium carbonate coating in distribution pipes.

Chemical feed facilities or alkali addition should conform to Chapter 3.

4.11.6 Carbon Dioxide Reduction by Aeration

The carbon dioxide content may be reduced by aeration. Aeration systems should meet the requirements of Section 4.8.

4.11.7 Water Unstable Due to Biochemical Activity

Water in the distribution system that is unstable due to biodegradation of organic matter in water (e.g., dead-end watermains), the biochemical action within the tubercles, and the reduction of sulfates to sulfides, should be prevented by maintenance of free and/or combined chlorine residual throughout the distribution system. Reducing the biological dissolved organic carbon (BDOC) and natural organic matter (NOM) prior to entering the distribution system may be considered to prevent the development of biologically unstable water.

4.11.8 Testing

Laboratory testing equipment should be provided for determining the effectiveness of stabilization treatments. Probes, coupons, etc., should be considered for in-situ measurement of corrosion in distribution systems.

4.12 TASTE AND ODOUR CONTROL

Provision should be made for control of taste and odour at all surface water treatment plants. Chemicals should be added sufficiently ahead of other treatment processes to assure adequate contact time. Where severe taste and odour problems are encountered, in-plant and/or pilot studies may be required. Consideration should be given to the flexibility of the equipment for various control processes.

4.12.1 Chlorination

Chlorination for taste and odour control should have adequate contact time. THM levels likely to result from use of chlorine to treat tastes and odours should be considered.

4.12.2 Chlorine Dioxide

Taste and odour control by chlorine dioxide should require proper storage and handling of sodium chlorite, as per Section 4.6.2.

4.12.3 Powdered Activated Carbon

Taste and odour control using powdered activated carbon (PAC) should meet the following requirements:

1. PAC should be added as early as possible in the treatment process to provide maximum contact time;

2. Flexibility to add PAC at several points is recommended;

3. PAC should not be applied near the point of chlorine addition or other oxidant;
4. PAC can be added as a pre-mixed slurry or by means of dry feed;
5. Continuous agitation should be provided to ensure that the PAC does not deposit in the slurry storage tank;
6. Provision should be made for adequate dust control;
7. Provision should made for a rate of PAC feed from 0.1 to 40 mg/L; and
8. PAC should be considered potentially combustible material and should be stored in a separate fire retardant building or room, equipped with explosion proof outlets, lights and motors.

4.12.4 Granular Activated Carbon

Granular activated carbon filters should meet the requirements of Section 4.5. Media for granular activated carbon filters and absorbers should meet the requirements of Section 4.5.1.5.

4.12.5 Aeration

See Section 4.8 for the requirements for aeration systems.

4.12.6 Potassium Permanganate

Potassium permanganate addition for taste and odour control should not result in discolouration of the treated water.

4.12.7 Ozone

Ozone, when used for taste and odour control, should be designed such that adequate contact time is achieved. Ozone is generally more desirable for treating water with high threshold odours.

4.12.8 Piloting Requirements

Any other method of taste and odour control should be subject to pilot testing and should meet the requirements of Section 2.2.3.2.

4.13 WASTE HANDLING

4.13.1 General

Provisions should be made for proper handling and disposal of water treatment plant wastes, whether they are sanitary wastes, laboratory wastes, clarifier sludge, spent filter backwash, softening sludge, brines, or neutralization chemicals. All waste discharges should be regulated by the Authority having jurisdiction. Water quality requirements imposed by the regulatory agency will dictate the allowable rate of discharge and discharge quality, which will dictate the treatment requirements, if any. The requirements indicated herein therefore should be considered minimum requirements and where a discrepancy exists between these minimum requirements and those of the Authority having jurisdiction, the latter should govern.

4.13.2 Sanitary Waste

Sanitary wastes from water treatment plants include waste from washroom facilities, kitchen facilities, lunch rooms and laboratory wastes. The sanitary waste from water treatment plants, pumping stations and other waterworks installations should receive treatment. Waste from these facilities should discharged directly to a sanitary sewer, when available and feasible, or to an adequate on-site sewage disposal system designed and constructed to meet the requirements of the province in which it is to be constructed.

4.13.3 Water Treatment Plant Residuals

The nature and treatability of the waste material to be produced as a result of the treatment process should be adequately characterized. Waste characterization, in addition to the ultimate disposal requirements, should be given a high degree of consideration in the planning and selection of water treatment processes. Alternative methods of reducing waste volumes should also be considered.

4.13.3.1 Brine Waste

Brine waste is produced from ion exchange plants, demineralization plants, or other plants which remove ions from solution. Water quality requirements imposed by the regulatory agency will dictate the allowable rate of discharge.

4.13.3.2 Lime Softening Sludge

Sludge from water treatment plants that use lime softening varies in quality and chemical characteristics and the quantity is often larger than stoichiometric calculations would indicate. The lime softening process typically produces a sludge with high concentrations of precipitates such as calcium carbonate, calcium sulfate, magnesium hydroxide, silica, iron oxides, aluminum oxides and unreacted lime. The sludges are typically of high solids content and are readily settleable. The high pH of this material can make it difficult to provide adequate treatment and disposal of this waste.

4.13.3.3 Coagulation Sludges

Typically, aluminum and/or iron coagulants are used in conventional surface water treatment plants. Therefore, the sludge from coagulation/flocculation and clarification systems is typically high in organic material, aluminum and/or iron, dissolved and colloidal contaminants and pathogens. These sludges can range from thick and readily settleable to light and slow to settle depending on the contaminants removed during the coagulation and clarification processes. In Atlantic Canada however, these materials are often difficult to settle due to the high organic matter content.

4.13.3.4 Spent Filter Backwash Water

Spent filter backwash water (SFBW) contains materials that are not removed during clarification and are subsequently removed during filtration. The concentration of solids in SFBW will depend on the efficiency of the coagulation/flocculation, clarification and filtration processes, as well as the amount of water used for backwashing the filters.

In Atlantic Canada, this material is often light and slow to settle due to high organic content in the metal hydroxide flocs in the SFBW. Therefore, the selection of treatment process is not an obvious one and may require piloting in some circumstances.

4.13.4 Quantity

An accurate means of measuring residuals/waste streams and their respective quantities should be provided.

4.13.5 Direct Discharge to Sewer

Where ultimate disposal is to be to a sanitary sewer, consideration should be given to the capacity of the sanitary sewer system and sewage treatment plant and, as a result, may require holding tanks to prevent overloading of sanitary sewer facilities. Discharge to sewage lagoons should also consider evaporation effects of the lagoons.

Disposal of plant process wastewater and sludges to municipal sewers may be limited by provincial regulations and/or municipal by-laws and consultation with the reviewing authority is recommended.

Discharge of lime sludge to sanitary sewers should be avoided and may only be used in situations where the sewerage system capacity is adequate to accommodate the lime sludge. Mixing of lime sludge with activated sludge waste may be considered as a means of co-disposal.

4.13.6 Waste Treatment

The choice of residuals treatment process will depend on the raw water, the main treatment plant processes as well as the discharge and ultimate disposal requirements. In cases where there is satisfactory operating data to confirm the suitability of a particular process does not exist for a given residuals stream, pilot testing should be performed and should meet the requirements of Section 2.2.3.2.

4.13.6.1 Waste Equalization and Mixing

Adequate storage should be provided to ensure a controlled discharge of waste over a 24 hour period. Equalization and continuous agitation should be provided for those wastes which are to be treated by high rate residuals treatment processes such as thickening/sedimentation, DAF, or membranes.

4.13.6.2 Lagoon Treatment

Lagoon systems should be designed such that they can be cleaned periodically and should be designed to provide a retention time between 15 and 30 days, with at least two (2) years of sludge storage. A minimum of two lagoons should be provided so that one system may be taken out of service for cleaning. An acceptable means of final sludge disposal should be provided. Provisions should be made to facilitate sludge removal.

Lagoon design should provide for:

1. Location free from flooding;

2. When necessary, dikes, deflecting gutters, or other means of diverting surface water away from or around the lagoons;

3. A minimum side water depth of 1.5 m;

4. A minimum freeboard of 0.9 m *(GLUMRB recommends 0.6 m; Atlantic Canada Sewage Treatment Manual suggests 0.9 m freeboard on sewage lagoons);*

5. Adjustable decanting device;

6. Low permeability liner;

7. Effluent sampling location;

8. Adequate safety and security provisions; and

9. Parallel operation ability.

Note that lagoons may not be sufficient for removal of aluminum levels to meet the Approved discharge requirements for some water treatment plants using aluminum-based coagulants and discharging to fresh water bodies. Careful consideration should be given to coagulant alternatives to alum in these circumstances. In addition, receiving water studies may be required by the regulatory authority to confirm the discharge aluminum levels proposed will not cause adverse impacts on fish species or benthic communities.

4.13.6.3 Thickening and Sedimentation

Thickening should refer to the process by which equalized clarifier sludge and/or backwash wastes are further concentrated in a thickening basin. Feed to the thickener should be as uniform as possible in both quality and quantity through providing both equalization and agitation. Design of gravity thickening units should be based on surface overflow rate and should not exceed 0.005 m/hr.

Sedimentation, with respect to waste treatment, should refer to the process by which residuals are reflocculated prior to settling. Sedimentation basins should be designed with a surface overflow rate between 0.3 and 0.6 m/hr.

Gravity thickening and sedimentation units should be designed with two trains and may be either circular or square tankage. Units should also be designed to minimize short-circuiting and to accommodate sludge removal as per the requirements of Section 4.4.1.

Coagulant addition, if necessary, should meet the requirements of Sections 4.2.

4.13.6.4 Dissolved Air Flotation

Dissolved air flotation may be applicable for treatment of water treatment plant residuals that are very light and would exhibit poor settleability. The design of DAF clarification systems for residuals should provide for a surface overflow rate ranging from 2.4 to 9.6 m/hr. DAF system design should also meet the requirements of Section 4.4.2. Coagulant addition, if necessary, should meet the requirements of Sections 4.2.

4.13.6.5 Membranes

Membranes may be suitable for the treatment of water treatment plant residuals. Careful consideration should be given to allowable flux rates and such would have to be confirmed through pilot testing as per Section 2.2.3.2.

4.13.6.6 Polymer Addition

Polymer addition has the potential to increase the allowable surface overflow rates for residuals treatment processes significantly. Equalization tankage and continuous agitation should be provided as per Section 4.13.5.1 to ensure consistent chemical feed can be maintained. Polymer system design should meet the requirements of Chapter 3.

4.13.6.7 Iron and Manganese Wastes

Iron and manganese waste or "red water" wastes can be treated using sand filtration, sedimentation basins, lagoons or discharge to a sanitary sewer. Discharge to a sanitary sewer should conform to Section 4.13.4.

Sand Filters

Sand filters should have the following features:

1. A total filter area adequate to dewater the applied solids;
2. Two filters should be provided, unless the filter is of size small enough that it may be cleaned and returned to service in one day;
3. The red water filter should have sufficient capacity to contain the entire backwash volume generated by washing all of the filters, unless the filters are washed on a rotating schedule and the flow through the filters is regulated by true rate flow controllers (sufficient volume should also be provided to properly dispose of the wash water involved);
4. The filter area should be such that no more than 600 mm of backwash water accumulates over the sand media at any time;
5. The filter should not be subjected to flooding by runoff water and should be constructed at an elevation that will facilitate maintenance;
6. Non-watertight structures should not be used for the construction of filter sidewalls;
7. Filter media should consist of minimum 300 mm sand, 75-100 mm of torpedo sand, and minimum 225 mm of supporting gravel;
8. Filter sand should have an effective size of 0.3 to 0.5 mm and a uniformity coefficient not to exceed 3.5;
9. The filter should be provided with adequate under-drainage collection system to permit satisfactory discharge of filtrate;
10. Provision should be made for sampling of filter effluent;
11. Overflow devices should not be permitted;

12. Provisions should be made for covering the filters during winter months;

13. Precautions should be taken to ensure cross-connection with treated water does not occur; and

14. Any deviations to the above should be subject to pilot testing requirements as per Section 2.2.3.2.

Lagoons

Lagoons should have the following features:

1. Volume should be 10 times the total quantity of water discharged during any 24 hour period;
2. A minimum sidewater depth of 1.0 m;
3. Minimum length to width ratio of 4:1 and a minimum width:depth ratio of 3:1;
4. Outlets and inlet located to minimize short-circuiting;
5. A weir outlet device with a weir length equal to or greater than the liquid depth; and
6. Velocity to be dissipated at the inlet.

4.13.7 Spent Filter Backwash Water Recycling

Spent filter backwash (SFBW) water recycling is practiced in many facilities throughout the United States and Canada (Arora *et. al.*, 2001). Waste recycling has been shown to be an effective method of water recovery (Arora *et. al.*, 2001; Cornwell and Lee, 1994; Cornwell and MacPhee, 2001; Edzwald *et. al.*, 2001). Furthermore, the recently instituted Filter Backwash Recycle Rule (USEPA, 2001) indicates that SFBW recycling may be acceptable provided hydraulic surges due to recycling are kept below 10% of the plant influent flow rate and provided the recycle is introduced at a location in the process train so as to ensure all recycle flows are subjected to all treatment processes at the respective plants.

SFBW recycle should be avoided, if possible. SFBW recycle may be considered on a site-specific basis and should be approved by the reviewing authority prior to implementation. In all cases of SFBW recycling, consideration should be given to possible treatment strategies for SFBW, prior to recycling.

4.13.8 Dewatering

(All from AWWA/ASCE/USEPA, 1996)

Methods of dewatering include the following:

a. Air/gravity drying processes:
   i. Sand drying beds;
   ii. Freeze-thaw beds;

  iii. Solar drying beds; and
  iv. Vacuum assisted drying beds.

b. Mechanical dewatering processes:
  i. Belt filter presses;
  ii. Centrifuges; and
  iii. Pressure filters.

A complete discussion on each of these dewatering processes is beyond the scope of this manual. Some general guidelines, however, are provided.

4.13.8.1 Air/Gravity Drying Processes

Sand drying beds dewater primarily by gravity drainage of water from the sludge by placing the sludge on a sand medium, and are more effective for lime sludges than for coagulant sludges. Loading rates are typically between 1.0 and 2.4 kg/m^2. Draining time is typically 3 to 4 days. Applied sludge depth should be 20-75 cm for coagulant sludges and 30-120 cm for lime sludges.

Freeze-assisted drying beds use a freeze-thaw cycle to break the molecular bonds with the water and the sludge, which greatly enhances the dewatering rate. These systems are more suitable for dewatering alum sludges in cold climates. Freeze-thaw systems should be designed using two (2) drying beds, each sized to accommodate one (1) year of sludge storage.

Solar drying beds use asphalt as a sub-base for dewatering of sludge. The heat effects promote faster drying. This process will not have widespread applicability in Atlantic Canada due to the local climate.

Vacuum-assisted drying beds provide a suction to the underside of a rigid, porous media plates upon which the residuals are placed, which draws the water from the sludge. Frequent plate cleaning and chemical sludge conditioning is typically required for this type of process.

Decanting and drainage systems should be provided and required solids concentration, climate, drainage discharge location and regulatory requirements should be considered. Sludge layers should be kept thin to maximize drying rates.

4.13.8.2 Mechanical Dewatering Processes

Belt and diaphragm filter presses dewater residuals by sandwiching sludge between two porous belts and are suitable for dewatering lime sludges to 50% - 60% and coagulant sludges to 15% - 20%. The applied pressure is typically in the 600 to 1,500 kPa range. Roller bearings should be designed to have an L-10 service life of approximately 300,000 hrs. A polymer conditioning system should be provided for all belt filter presses. Consideration should also be given to desired cake solids content, conditioning requirements, pressure requirements, belt speed, belt tension, belt type and belt mesh size.

Centrifuges dewater residuals by forcing water from solids under high centrifugal forces. Both concurrent and counter-current designs are acceptable. Design criteria will be proprietary in nature and the manufacturer should be consulted in each case a centrifuge is being considered. A polymer conditioning system should be provided for all centrifuge systems.

Similar to air dewatering systems, decanting and drainage systems should be provided and required solids concentration, drainage discharge location and regulatory requirements should be considered.

4.13.8.3 Comparison of Dewatering Processes

The relative performance of the dewatering processes described above are provided in Table 4.6:

Table 4.6: Relative performance of dewatering processes

	Percent Solids Content	
Process	Lime Sludge	Coagulant Sludge
Gravity thickening	15 – 30	3 – 4
Scroll centrifuge	55 - 65	10 – 15
Belt filter press	No data	10 – 15
Vacuum filter	45 - 65	No data
Pressure filter	55 – 70	35 – 45
Sand drying bed	50	20 – 25
Storage lagoon	50 – 60	7 – 15
Freeze-thaw bed	No data	No data

4.13.9 Sludge Disposal

The application of liquid sludge to farmland should be considered as a method of ultimate disposal. Prior to land application, a chemical analysis of the sludge should be completed, including calcium and heavy metals. Approval from the Authority having jurisdiction should also be obtained. When this method is utilized, the following provisions should be made:

1. Transport of sludge by vehicle or pipeline should incorporate a plan or design which prevents spillage or leakage;

2. Interim storage areas at the application site should be kept to a minimum and

facilities should be provided to prevent wash off of sludge and/or flooding;

3. Sludge should not be applied to land where wash off could occur unless provisions are made for immediate incorporation into the soil;

4. An acceptable method of incorporating sludge into the soil should be provided prior to land application;

5. Trace metal loadings to the soil should be limited;

6. Each area of land to receive lime sludge should be considered individually and a determination made as to the amount of sludge needed to raise the soil pH to the optimum for the crop to be grown; and

7. Mechanical dewatering or calcination of lime sludges may be considered, provided pilot studies (see Section 2.2.3.2) are conducted.

Landfill disposal may be considered provided the landfill is capable of accepting the waste.

Drying beds for lime sludge are not recommended.

4.14 EMERGING TECHNOLOGIES

Due to increasingly stringent regulatory requirements, there is a need to develop cost-effective process alternatives so that water purveyors can provide the required level of service at an affordable cost. This usually results in improvements in process loading rates to reduce footprints and/or development of technologies that achieve more stringent water quality objectives with less equipment and infrastructure. The application of emerging technologies is therefore encouraged.

A complete discussion of all available emerging technologies is beyond the scope of this manual. All emerging technologies (i.e., those which are not included in this manual) should, however, be subject to the pilot testing requirements of Section 2.2.3.2. An engineering report should also be submitted to the reviewing authority prior to pilot testing. Pilot testing should then be followed with a report, which outlines the results, design criteria, conclusions and recommendations prior to proceeding with the development of plans and specifications for the proposed works.

Chapter 5.0 PUMPING FACILITIES

5.1 FACILITY TYPES

5.1.1 Raw Water Pumping Facility

Raw water pumping facilities generally pump raw (non-potable) water from a surface water supply to a water treatment plant. The raw water is typically pumped from a river, natural lake, or an artificial reservoir. Depending on the source and the ultimate use of the water, raw water pumping facilities are usually a combination of only three basic components:

a) raw water intake structure;

b) the pumping facilities; and

c) [illegible]ing facilities (which may or may not be required). Most raw water pumping facilities are shoreline installations.

5.1.2 Booster Pumping Facility

Water distribution systems may have incorporated within them water booster stations. The purpose of these stations is to maintain adequate pressures and flows in water distribution systems as a result of changes in ground elevation and/or distance from the source of supply. Booster pumping facilities serve specific areas within a water distribution system, based on defined limits. These areas are generally isolated from the remainder of the distribution system.

Booster pumping facilities can generally be divided into two main categories: a) in-line and b) distribution facilities. In-line booster stations take suction from an incoming pipeline, increase the line pressure, and discharge it to another pipeline. Distribution booster stations typically take suction from storage and maintain a given pressure (within limits) for supply in a distribution system at wide ranges of demand. Either type of facility may have incorporated with part of their operation, elevated or ground storage reservoirs on the discharge side of the station. These reservoirs will, in effect, serve to supplement extreme production requirements, such as peak hour and fire flow demands.

5.1.3 Fire Pumping Facility

Fire pump facilities are incorporated within water distribution systems to provide adequate pressures and flows under fire demand conditions. These types of facilities are required when changes in ground elevation, distance from source of supply, or lack of a central water distribution system limit the amount of available fire flows and pressures under conventional gravity supply. Fire pump facilities typically take suction from storage and maintain a minimum required pressure under fire flow conditions.

5.2 FACILITY CONSTRUCTION

5.2.1 General

Pumping facilities should be designed to maintain the potable water quality of pumped water. Subsurface pits or pump rooms and inaccessible installations should be avoided. No pumping station should be subject to flooding.

5.2.2 Location

The pumping station should be located such that the proposed site will meet the requirements for sanitary protection of water quality, hydraulics of the system and protection against interruption of service by fire, flood or any other hazard.

5.2.2.1 Site Protection

The station should be:

a) Elevated to a minimum one metre above the 100-year flood elevation, or one metre above the highest recorded flood elevation, whichever is higher, or protected to such elevations;

b) Readily accessible at all times unless permitted to be out of service for the period of inaccessibility;

c) Graded around the station so as to lead surface drainage away from the station;

d) Protected to prevent vandalism and entrance by animals or unauthorized persons; and

e) Located off street right-of-way in an appropriate area designated for pumping station purposes.

5.2.3 Pumping Stations

Pumping stations should:

a) Include a pump station building of adequate size to accommodate the pumps, pump motors, control panel, auxiliary power supply, oil tank, any required future pumping equipment and other accessories. These items should be located in the building taking into consideration safety for operators and convenient access for maintenance;

b) Include a pump station building of which the design and construction should meet the requirements of the latest edition of the National Building

Code, and should also meet the specific requirements of the Owner.

c) Have a floor elevation of at least 150 mm above the finished external ground surface;

d) Have underground structure waterproofed;

e) Have all floors drained in such a manner that the quality of the potable water will not be endangered. All floors should slope at least 75 mm in every 3 metres to a suitable drain;

f) Provide a suitable outlet for drainage for pump glands without discharging on the floor;

g) Have suitable vehicle access to allow for convenient equipment servicing;

h) Have all interior wall surfaces, doors and trim painted to a colour scheme approved by the Owner; and

i) Have outward opening doors.

5.2.4 Suction Well

Suction wells should:

a) Be watertight;

b) Have floors sloped to permit removal of water and entrained solids;

c) Be covered or otherwise protected against contamination; and

d) Have two pumping compartments with suitable valving or other means to allow one suction well to be taken out of service for inspection, cleaning, maintenance or repair, without disrupting service.

5.2.5 Equipment Servicing

Pump stations should be provided with:

a) Crane-ways, hoist beams, eyebolts, or other adequate facilities for servicing or removal of pumps, motors or other heavy equipment;

b) Openings in floors, roofs or wherever else needed for removal of heavy or bulky equipment; and

c) A convenient tool board, or other facilities as needed, for proper maintenance of the equipment.

5.2.6 Stairways and Ladders

Stairways or ladders should:

a) Be provided between all floors, and in pits or compartments which must be entered; and

b) Have handrails on both sides, and treads of non-slip materials. Stairs are preferred in areas where there is frequent traffic or where supplies are transported by hand. They should have risers not exceeding 230 mm and treads wide enough for safety.

5.2.7 Heating

Provisions should be made for adequate heating for:

a) The comfort of the operator;

b) The safe and efficient operation of the equipment.

Pump houses not occupied by personnel should be heated to prevent freezing.

5.2.8 Ventilation

Ventilation should conform to existing local and provincial codes. Adequate ventilation should be provided for all pumping stations. Ventilation equipment must meet the requirements of the Owner, and, as a minimum, must ensure that sufficient ventilation is supplied so that heat generated by electrical equipment is adequately dissipated. Forced ventilation of at least six changes of air per hour should be provided for:

a) All confined rooms, compartments, pits and other enclosures below ground floor; and

b) Any area where unsafe atmosphere may develop or where excessive heat may be built up.

5.2.9 Dehumidification

Dehumidification should be provided in areas where excess moisture could cause safety hazards or damage.

5.2.10 Lighting

Pump stations should be adequately lighted throughout. All electrical work should conform to the requirements of the Canadian Electrical Code and to relevant provincial codes.

5.2.11 Sanitary and Other Conveniences

All pumping stations that are manned for extended periods should be provided with potable water, lavatory and toilet facilities. Acceptable options for the disposal of wastewater include, but are not limited to, a municipal system, on-site sewage disposal systems, or a holding tank.

5.3 PUMPS

At least two pumping units should be provided. With any pump out of service, the remaining pump or pumps should be capable of providing the maximum pumping demand of the system. The pumping units should:

a) Have ample capacity to supply the peak demand against the required distribution system pressure without dangerous overloading;

b) Be driven by prime movers able to meet the maximum horsepower condition of the pumps;

c) Be provided with readily available spare parts and tools; and

d) Be served by control equipment that has proper heater and overload protection for air temperature encountered.

5.3.1 Selection

Selection of the appropriate pump is dependent on the requirements and conditions under which the equipment will operate, as stated below.

5.3.1.1 Water Quality

Water quality can have a significant effect on choice of pumping unit(s). Differences will almost certainly exist when considering raw water and potable water pumps, such as:

- Aggressiveness of the water can influence choice of material of construction;
- Suspended solids (particularly in raw water) may demand higher specification for seals and abrasion resistance within pump; and
- Erosion due to high particle content may cause premature performance decline, and large particles may require more open impeller design.

5.3.1.2 System Head Curves

A clear understanding is required of the process and the system in which the pumping equipment will operate. Development of system head curves showing the relationship between flow rate and hydraulic losses is required. Allowances for system performance decline over time due to corrosion, scale etc. and future requirements is essential.

5.3.1.3 Modes of Operation

System operating modes are important considerations when specifying pumping equipment. The following operational parameters need to be considered:

- Continuous or intermittent pump operation mode;
- Differences in head and flow rate requirements;
- Pump operation in series or parallel; and
- Maintenance requirements.

5.3.1.4 Pump Flow / Head Margins

Pumps are normally specified with a capacity margin above what has been determined necessary for the process. In addition, the calculated system head losses are also determined conservatively. This is required because:

- System design requires many assumptions for pump selection, some of these assumptions may prove to be incorrect;
- During the design life, system conditions will change and pump performance will decline;
- Pipe networks invariably change; and
- System hydraulics will change due to corrosion, scaling etc.

Pumps should be selected to work within a maximum margin of 20% of best efficiency point. Care must be taken when applying margins that a pump is not oversized. A total head that is too large may cause problems to the system, or a flow that is too great may have costly penalties in energy costs. In the case of centrifugal pumps, impellers can be upgraded and/or additional stages can be added over time.

5.3.1.5 Type of Pump Control

The type of control for the required pump(s) is an important consideration for pump specification and selection. A control valve (not normally supplied by the pump manufacturer) may be required to adjust the system curve over the life of the unit(s). Flow sensing control provides the most stable operation for most systems and pressure control can have a significant effect on the operation of a pump, in particular if it is operating on a flat part of the performance curve. Temperature and level sensing controls may also be required. A continuously open by-pass may also be required for pumps operating in the shut off position to prevent pump damage.

5.3.1.6 Future System Changes

When future system demand can be predicted with a degree of certainty, the system can be designed with that in mind. Rather than selecting a pump that is operating at the high end of it's preferred operating region, the next sized pump operating at the beginning of the preferred operating range might be considered. In addition the capability of installing a larger impeller to handle future requirements must be considered. Minimizing capital and operating costs should be considered. Oversizing pumps is not normal practice. Pumps should operate efficiently and reliably.

5.3.2 Suction Lift Pumps

Suction lift pumps should:

a) Be avoided, if possible; and

b) Be within allowable limits, preferably less than 5 metres.

If suction lift pumping is necessary, provision should be made for priming the pumps.

5.3.3 Priming

Prime water should not be of lesser sanitary quality than that of the water being pumped. Means should be provided to prevent either backpressure or backsiphonage backflow. When an air-operated ejector is used, the screened intake should draw clean air from a point at least 3 metres above the ground or other source of possible contamination, unless the air is filtered by an apparatus approved by the reviewing authority. Vacuum priming may be used.

5.4 BOOSTER PUMPS

In addition to requirements outlined in this Chapter, the following also applies. Booster pumps should be located or controlled so that:

a) They will not produce negative pressure in their suction lines;

b) The intake pressure should be at least 140 kPa (20 psi) when the pump is in normal operation;

c) Automatic cutoff or low pressure controller should maintain at least 70 kPa (10 psi) in the suction line under all operating conditions;

d) Automatic or remote control devices should have a range between the start and cutoff pressure which will prevent excessive cycling; and

e) A bypass is available.

Each booster pumping station should contain not less than two pumps with capacities such that peak demand can be satisfied with the largest pump out of service.

5.4.1 Metering

All booster pumping stations should contain a totalizer meter.

5.4.2 Individual Home Booster Pumps

Individual home booster pumps should be avoided for individual service from the public water supply main.

5.5 AUTOMATIC AND REMOTE CONTROLLED STATIONS

All automatic stations should be provided with automatic signaling apparatus which will report when the station is out of service. All remote controlled stations should be electrically operated and controlled and should have signaling instrumentation of proven performance. Installation of instrumentation equipment should conform with the applicable provincial and local electrical codes and the Canadian Electrical Code.

5.6 APPURTENANCES

5.6.1 Isolation Valves

Pumps should be adequately valved to permit satisfactory operation, maintenance and repair of the equipment. Valves may be either of the gate or butterfly type, and should be installed on the suction and discharge line of each pump. Typically, on larger installations (i.e., 350 mm or greater), butterfly valves should be utilized. Gate valves, especially for suction isolation, may be utilized for smaller sized piping.

5.6.2 Check Valves

A self-closing check valve must be incorporated in the discharge of each pump unit between the pump and the isolation valve. It should be designed in such a way that if pump flow is lost, the valve will close automatically. The type and arrangement of check valves and discharge valves is dependent on the potential hydraulic transients that might be experienced in the pumping station.

If foot valves are necessary, they should have a net valve area of 2 1/2 times the area of the suction pipe and they should be screened.

5.6.3 Suction and Discharge Piping

In general, suction and discharge piping should be as follows:

a) Designed and arranged to provided easy access for maintenance;

b) Designed so that the friction losses will be minimized;

c) Not be subject to contamination;

d) Have watertight joints;

e) Protected against surge or water hammer and provided with suitable restraints where necessary;

f) Each pump should have an individual suction lines and be manifolded to ensure similar hydraulic and operating conditions, such that similar hydraulic operating conditions exist for each pump;

g) Properly supported and designed with appropriate fittings to allow for expansion and contraction;

h) Finished, treated and painted to prevent rusting. Colour scheme and paint types should be approved by the Owner;

i) Have corrosion resistant fitted bolts;

j) Include couplings where required to provide sufficient flexibility to allow removal of equipment and valves; and

k) Pipe material capable of functioning in the pumping application, and should be approved by the Owner.

5.6.4 Gauges and Meters

Each pump:

a) Should have a standard pressure gauge on its discharge line;

b) Should have a compound gauge on its suction line; and

c) Should have recording gauges where applicable.

The station should have indicating, totalizing, and recording metering of the total water pumped.

5.6.5 Water Seals

Water seals should not be supplied with water of a lesser sanitary quality than that of the water being pumped. Where pumps are sealed with potable water and are pumping water of lesser sanitary quality, the seal should:

a) Be provided with either an approved reduced pressure principle backflow preventer or a break tank open to atmospheric pressure; and

b) Where a break tank is provided, have an air gap of at least 150 mm or two pipe diameters, whichever is greater, between the feeder line and the flood rim of the tank.

5.6.6 Surge Arrestor Systems

A hydraulic transient analysis should be undertaken for each pumping station to be designed, to ensure that the transients resulting from pumps starting, stopping, full load rejection during power failure, etc., do not adversely affect either of the customers on the water system, or the piping in the station or the system. Typically, methods of surge protection that can be used to protect pumping stations include:

a) Surge anticipator systems that dissipate over-pressure from the discharge lines;

b) Slow closing and opening control valves on pump discharges;

c) Hydropneumatic surge tanks on discharge headers;

d) Variable speed pumping units; and

e) Water storage reservoir in the vicinity.

5.7 ELECTRICAL

5.7.1 Power Supply

The pumping station should be provided with a three-phase power supply. Design and installation of the power supply system should meet all applicable and relevant standards and codes.

5.7.2 Pump Motor

Each pump should be operated by an energy efficient electrical motor capable of operating the pump over the full range of load conditions. Motors should be located such that they cannot be flooded should a pipe failure occur.

5.7.3 Stand-by Power

Full stand-by power supply should be provided utilizing a stand-by generator. The generator should be capable of providing continuous electrical power during any interruption of the normal power supply. The stand-by power unit should be designed with adequate capacity to operate fire and domestic pumps, control and monitoring systems, and heating and lighting systems within the pump house.

The generating system should include the following items:

a) Diesel or alternate fuel powered engine;

b) Alternator;

c) Control Panel;

d) Automatic change over equipment;

e) Automatic ventilation system;

f) Battery charger and battery; and

g) Fuel supply unit.

Fuel storage and supply lines must be designed to protect against spills and leaks.

For small pumping facilities, portable stand-by power units may be used when a fixed exterior electrical connection is provided.

5.7.4 Controls

Pumps, their prime movers and accessories, should be controlled in such a manner that they will operate at rated capacity without dangerous overload. Where two or more pumps are installed, provision should be made for alternation. Provision should be made to prevent energizing the motor in the event of a backspin cycle. Equipment should be provided or other arrangements made to prevent surge pressures from activating controls which switch on pumps or activate other equipment outside the normal design cycle of operation.

All electrical equipment should be located in an accessible location above grade with a clear access of 1 meter around all pumps and motors. All panels and controls should have NEMA 3 enclosures.

All floor mounted electrical equipment must be mounted on 100 mm high housekeeping pads.

5.8 SAFETY PRECAUTIONS

Pumping stations and appurtenances should be designed in such a manner as to ensure the safety of operations, in accordance with all applicable Municipal, Provincial and Federal regulations including the Occupational Health and Safety Act. All moving equipment should be covered with suitable guards to prevent accidental contact.

Equipment that starts automatically should be designed to ensure that operators are aware of this condition. Lock-outs on all equipment should be supplied to ensure that the equipment is completely out of service when maintenance or servicing is being carried out.

5.9 STATION MONITORING

Typically, pumping station functions should be monitored to ensure that the station is performing satisfactorily. Monitoring signals and alarms are normally transmitted to a central location which is manned on a 24-hour basis. In the case of very small stations, a single alarm, covering a variety of points, may be acceptable. In larger stations, typically the following signals and alarms should be considered for transmission to a central monitoring point:

Signals

a) Station flow; and

b) Station pressure.

Alarm Points

a) Pump alarms, including:
   i. Discharge pressure too low;
   ii. Discharge pressure too high; and
   iii. Motor temperature alarm.

b) Station alarm points, including:
   i. Building temperature alarm;
   ii. Building fire alarm;

iii. Building station flood;
iv. Power failure alarm;
v. Illegal entry alarm; and
vi. Surge valve alarm.

Chapter 6.0 TREATED WATER STORAGE FACILITIES

6.1 GENERAL

Water storage is essential for meeting all of the domestic, public, industrial, commercial and fire-flow demands of almost all public water systems. This section addresses the requirements of treated water storage.

6.2 DEFINITIONS

6.2.1 Age of Treated Water

For the purposes of this manual the age of treated water is measured as the time from when disinfecting took place.

6.2.2 Detention Time

Detention time (sometimes known as retention time or residence time) is defined as the period during which the treated water remains in storage prior to entering the distribution system. This may not be a fixed period and is dependent on utilization of the treated water and mixing of the treated water in storage. There could also be significant detention time within the distribution system prior to water reaching the first customer.

6.2.3 Elevated Tank

Elevated tanks generally consist of a water tank supported by a steel or concrete tower that does not form part of the storage volume. In general, an elevated tank supplies peak balancing flows. See figure 6.1a

6.2.4 Standpipe

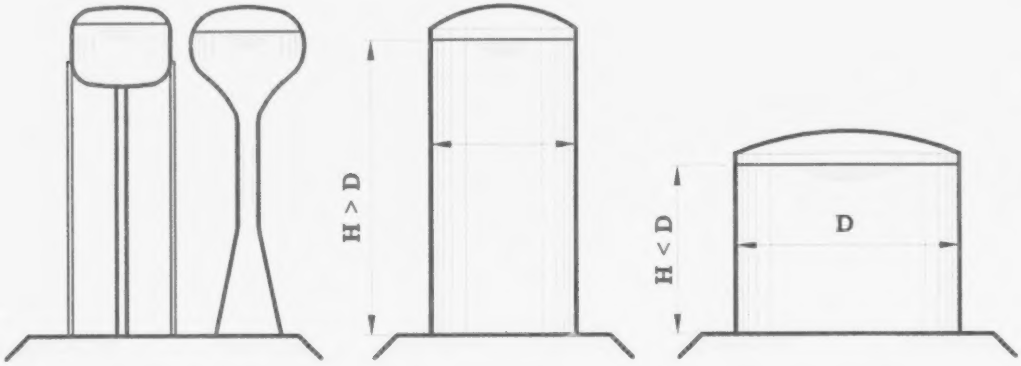
A standpipe is a tank that is located on the ground surface and has a greater height than diameter. In most installations water in the upper portion of the tank is used for peak flow balancing (equalization), the remaining volume is for fire flow and emergency storage. See figure 6.1b

6.2.5 Reservoir

A treated water reservoir is a storage facility where the width/diameter is typically greater than the height and usually applies to large storage facilities.

6.2.5.1 Above-Ground Reservoir

An above-ground reservoir is a water storage structure that is primarily above ground. See figure 6.1c.



a. Elevated Tank b. Standpipe c. Reservoir

Figure 6.1: Above Ground Storage

6.2.5.2 In-Ground Reservoir

An in-ground reservoir is a water storage structure that is partially below the nominal surface of the ground. A typical construction has the reservoir located 50% above and 50% below ground. See figure 6.2.

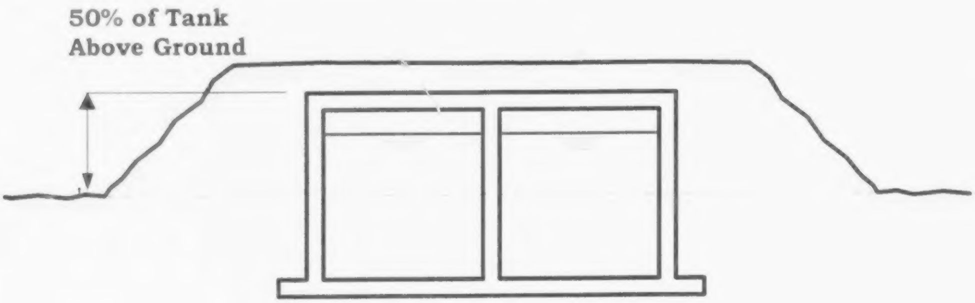


Figure 6.2: In-Ground Reservoir

6.2.6 Hydropneumatic Systems

Hydropneumatic tanks are partly filled with water and partly filled with air. They are generally steel pressure tanks, with a flexible membrane that separates the air and the water. Air is compressed in the upper part of the tank and is used to maintain water pressure in the distribution system when demand exceeds the pump capacity. It also reduces on-off cycling of pumps. See figure 6.3.

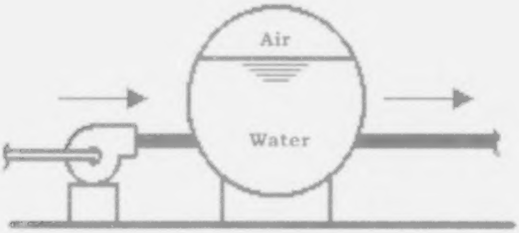


Figure 6.3: Pressure (Hydropneumatic) Tank Storage

6.3 MATERIALS OF CONSTRUCTION

6.3.1 Standards and Materials Selection

Storage facilities, including pipes, fittings and valves, should conform to the latest standards issued by the CSA or AWWA, and be acceptable to the reviewing authority. In the absence of such standards, materials meeting applicable Product Standards and acceptable to the reviewing authority may be selected. Special attention should be given to selecting pipe materials that will protect against internal and external pipe corrosion. All products should comply with CSA/ANSI standards. Any material that comes in contact with drinking water must comply with NSF Standard 61.

Other materials of construction are acceptable when properly designed to meet the requirements of treated water storage including concrete.

6.3.2 Steel Construction

Steel structures should follow the current AWWA standards (D100, D101, D102, D103, D104) concerning steel tanks, standpipes, reservoirs, and elevated tanks wherever they are applicable. Painted welded steel and pre-finished bolted steel tanks are options for treated water storage tanks.

6.3.3 Concrete Construction

Concrete structures should follow the current AWWA standards (D101, D110) concerning concrete tanks, standpipes, reservoirs, and elevated tanks wherever they are applicable.

6.4 DESIGN CRITERIA

The top water level and location of the storage structures will be determined by the hydraulic analysis undertaken for the design of the distribution system, to result in acceptable service pressures throughout the existing and future service areas.

The materials and designs used for treated water storage structures should provide stability and durability as well as protect the quality of the stored water. The following subsections outline criteria that should be considered when designing treated water storage facilities. AWWA standards that apply to water storage facilities are, D100, D101, D102, D103, D104, D110, D115, D120 & D130.

6.4.1 Demand Equalization (Peak Balancing Storage)

The demand for water normally changes throughout the day and night. If treated water is not available from storage, the wells and/or treatment plant must have sufficient capacity to meet the demand at peak flow. This capacity is not generally practical or economical. With adequate storage, water can be treated or supplied to the system at a relatively uniform rate over a 24 hour period with peak balancing flows at high demand periods during the day being supplied by water storage tanks.

6.4.2 System Operation (Convenience)

In some situations, storage is provided to allow a treatment plant to be operated for only one or two shifts, thereby reducing personnel costs. In this situation storage provides the water required for the periods of time when the plant shuts down.

6.4.3 Smoothing Pumping Requirements

The demand for water is continually changing in all water systems, depending on time of day, day of the week, weather conditions and many other factors. If there is no storage at all, the utility has to continually match the changing demand by selecting pumps of varying sizes. Frequent cycling of pumps causes increased wear on controls and motors. It also increases energy costs. Adequate elevated storage can minimize this effect by providing peak flow balancing capacity.

6.4.4 Reducing Power Costs

Storage allows for pumping costs to be reduced, by reducing start-ups, avoiding using large pumps at peak demands and also benefiting from off-peak rates offered by the electricity utility during the night.

6.4.5 Emergency Storage

During periods of power failure, mechanical or pipeline breakdown or maintenance when use of source water is prevented, there is a need for emergency storage.

6.4.6 Fire Storage

Fire demands may not occur very often, however, when it does occur, the rate of water use is usually much greater than for domestic peak demand. Also, the required fire storage volume can account for as much as 50% of total capacity of the reservoirs.

6.4.7 Pressure Surge Relief

When pumps are turned on and off and when valves are opened and closed, large pressure changes can occur throughout the distribution system which can damage pipes and appurtenances. Water storage tanks provide some assistance in absorbing pressure surges.

6.4.8 Detention Time

The time that water stays in storage after disinfectants are added, but before the water is delivered to the first customer, can be counted towards the disinfectant contact time. It is recommended, however, that the disinfection process be complete prior to water entering the distribution storage and/or the transmission and distribution systems, and that a minimum chlorine residual is maintained to ensure water quality is maintained throughout the system.

Supplemental chlorination may be required to maintain minimum chlorine residuals in water from water storage facilities that has insufficient residual chlorine.

A detailed design of the inlet, outlet and baffling is required where storage facilities are used as supplemental chlorination stations.

6.4.9 Blending of Water Sources

Some water systems use water from two or more sources, with each source having different water quality. The feasibility of the blending of sources should be investigated, as the chemical quality of blended water may affect the integrity of the distribution system.

6.5 SIZING OF WATER STORAGE FACILITIES

Storage facilities should have sufficient capacity, as determined from engineering studies, to meet the required domestic demands, and where fire protection is provided, fire flow demands. Emergency storage volumes should be provided to supply demands in the event of pipeline or equipment breakdowns or maintenance shutdowns. Excessive storage capacity should be avoided where water quality deterioration may occur.

The total water storage requirements for a given water supply system where the treatment plant is capable of satisfying only the maximum day demand may be calculated using the following equation:

S = A+B+C

Where:

S = Total storage requirement, m^3

A = Fire Storage, m^3 (equal to require fire flow over required duration)

B = Peak Balancing Storage, m^3 (25% of maximum day demand)

C = Emergency Storage, m^3 (25% of A+B)

Notes

1. The above equation is for the calculation of the storage requirement for a system where the water treatment plant is capable of satisfying only the maximum day demand. For situations where the water treatment plant can supply more, the above storage requirements can be reduced accordingly.

2. The maximum day demand referred to in the foregoing equation should be calculated using the factors in Table 7.1, unless there is existing flow data available to support the use of different factors. Where existing data is available, the required storage should be calculated on the basis of an evaluation of the flow characteristics within the system.

3. Should the proponent have decided to provide a potable water supply and distribution system ***not*** capable of providing fire protection, the usable volume of storage to be provided should be 25% of design year maximum day plus 40% of the design year average day.

4. The designer should recognize that this formula for calculating treated water storage requirements must be supplemented with the plant water storage required for the operation of the water treatment facility, i.e. backwash and domestic use.

Source: Guidelines for the Design of Water Storage Facilities,
Ontario Ministry of the Environment, 1985

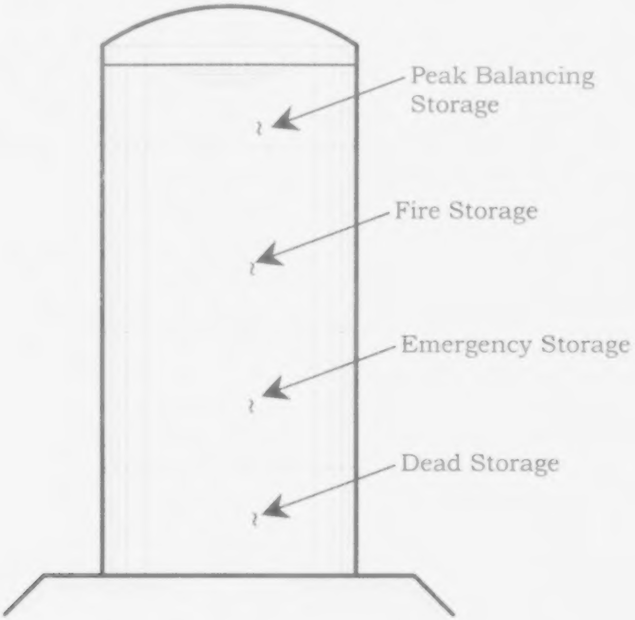


Figure 6.4: Sizing of Water Storage

6.5.1 Fire Flow Storage Requirements

The level of fire protection is the responsibility of the municipality. Fire flow requirements, typically established by the appropriate IAO, should be satisfied where fire protection is provided. The level of storage may be further reduced if the water treatment plant is capable of supplying portions of the required fire-flow volume.

6.5.2 Peak Balancing Storage Requirements

Peak balancing storage also known as operational storage is directly related to the amount of water necessary to meet peak demands. The intent of peak balancing storage is to make up the difference between the consumers' peak demands and the system's available supply. With peak balancing storage, system pressures are typically improved and stabilized. The value of the peak balancing storage is a function of the diurnal demand fluctuation in a community and is **commonly estimated at 25%** of the total maximum day demand.

6.5.3 Emergency Storage

This is the volume of water recommended to meet the demand during maintenance shut-downs or emergency situations, such as source of supply failures, watermain failures, electrical power outages, or natural disasters. The amount of emergency storage included with a particular water system is not set, but is typically based on an assessment of risk and desired degree of system dependability.

In considering emergency storage, it is acceptable to evaluate providing significantly reduced supplies during emergencies.

In the absence of clear information, 15% of projected average daily design flow can be used, or 25% of (Peak Balancing + Fire Flow)

6.5.4 Dead Storage

If a storage structure is of a type where only the upper portion of the water provides a useful function, such as maintaining usable system pressure, the remaining lower portion is considered **dead storage**. Dead storage can be considered useful if the water from the lower portion of the storage structure can be withdrawn by pumps during a fire or other emergency. Where dead storage is present there must be adequate measures taken to circulate the water through the tank to maintain quality and prevent freezing. Unusable dead storage should be avoided wherever possible.

6.5.5 Turnover and Water Quality

Deterioration in water quality is frequently associated with the age of the water. Loss of disinfectant residual, formation of disinfectant by-products, and bacterial re-growth can all result from aging of water. As a result, an implicit objective in both design and operation of distribution system storage facilities is the minimization of detention time and the avoidance of volumes of water that remain in the storage facility for long periods. The allowable detention time should depend on the quality of the water, its reactivity, the type of disinfectant used and the travel time before and after the water's entry into the storage facility. A maximum 72 hour turnover is a reasonable guideline. If it is not possible to have sufficient turnover of water in the storage facility, supplemental disinfection may be required.

6.5.6 Plant Storage

The designer should recognize the need to calculate, in addition to distribution storage requirements, the requirement for the operation of the water treatment facility, i.e. backwash and domestic use.

6.5.6.1 Clearwell Storage

Clearwell storage should be sized, in conjunction with distribution system storage, to avoid frequent on/off cycling of the treated water pumps. A minimum of two compartments along with adequate measures for circulation should be provided. Clearwells that can be depleted should not be used to achieve the required chlorine contact times. A separate contact tank should be provided to meet the disinfection requirements as per chapter 4.

6.6 LOCATION OF DISTRIBUTION STORAGE

The location of distribution storage is closely associated with the system hydraulics and water demands in various parts of the system. Location of the storage facilities at natural 'high' points within the area being served by the water system allows for gravitational advantage and potential considerable cost savings. The site selection process is often also affected by the availability of appropriate land and public acceptance of the structure.

6.6.1 Elevated Storage

Elevated storage includes elevated tanks and the upper portion of water stored within standpipes (see definitions at start of this chapter). Elevated storage facilities that have existed for several years rarely bother the public, however property owners will often object to a new one being built near their homes. Designs can be very pleasing and landscaping and colours can be used to minimize or even enhance the visual effect. This may not however be enough to overcome the objections of the local community and it may be necessary to build water elevated storage facilities at non-ideal locations from both topographic and hydraulic perspectives. Industrial zones may provide some opportunities, otherwise alternative facilities using above-ground and in-ground water storage and pumps may be required.

6.6.2 Above Ground and In-Ground Storage Reservoirs

Low level above ground and in-ground storage reservoirs are generally used where a large quantity of water must be stored. A relatively large parcel of land is required to accommodate both the reservoir and the accompanying pump station.

The following are considered minimum requirements:

a) The bottom of above-ground reservoirs and standpipes should be placed at the normal ground surface and should be above maximum flood level based on a 100 year flood;

b) When the bottom of the storage reservoir must be below normal ground surface, the in-ground reservoir should be placed above the groundwater table. Typically at least 50 per cent of the water depth should be above grade. Sewers, drains, standing water, and similar sources of possible contamination must be kept at least 15m from the reservoir; and

c) The top of an in-ground reservoir should not be less than 600mm above normal ground surface. Clearwells constructed under filters may be exempted from this requirement when the total design gives the same protections.

6.7 FACILITY REQUIREMENTS

6.7.1 Inlet/Outlet and Baffle Wall

A detailed design of the inlet, and outlet and, if required – baffle walls, mixing, etc., is required to ensure maximum turnover of water in a storage tank. A publication such as "Maintaining Water Quality in Finished Water Storage Facilities" by the AWWA Research Foundation should be referenced.

6.7.2 Level Control

Adequate controls should be provided to maintain levels in distribution system storage structures. Level indicating devices should be provided at a central location. Key issues are:

a) Pumps should be controlled from tank levels with the signal transmitted by telemetry equipment when any appreciable head loss occurs in the distribution system between the source and the storage structure;

b) Altitude valves or equipment controls are required to control pump on-off cycles or gravity flow to and from the tank to maintain the system pressures and avoid overflows;

c) Overflow and low-level warnings or alarms should be located at places in the community where they will be under responsible surveillance 24 hours a day; and

d) Changes in water level in a storage tank during daily domestic water demands should be limited to a maximum 9 m to stabilize pressure fluctuations within the distribution system.

6.7.3 Overflow

All above ground water storage structures should be provided with an overflow which is brought down to an elevation between 300mm and 600mm above the ground surface, and discharges over a drainage inlet structure or a splash plate. An overflow should not be connected directly to a sewer or a storm drain. All overflow pipes should be located so that any discharge is visible.

When an internal overflow pipe is used on elevated tanks, it should be located in the access tube. For vertical drops on other types of storage facilities, the overflow pipe should be located on the outside of the structure.

The overflow of a ground-level structure should open downward and be screened with mesh non-corrodible screen installed within the pipe at a location least susceptible to damage by vandalism. Overflows should be located at sufficient elevation to prevent the entrance of surface water. A backflow preventer should be installed on all overflows, on in-ground or low elevation reservoirs.

The overflow pipe should be of sufficient diameter to permit the wasting of water in excess of the filling rate.

Consideration should be given to downgrade receiving areas of overflow water. Adequate surface detention should be provided to prevent soil erosion and to provide safe dissipation of chlorine.

The discharge must not be directed to natural water bodies. Discharge in residential areas should be contained to appropriate and controlled storm water channels.

6.7.4 Drainage of Storage Structures

Water storage structures which provide pressure directly to the distribution system should be designed so they can be isolated from the distribution system and drained for cleaning or maintenance without necessitating loss of pressure in the distribution system. The drain should discharge to the ground surface with no direct connection to a sewer or municipal storm drain, and should be located at least 300 mm above ground surface.

Water that is drained from storage structures should be dechlorinated prior to discharge to the environment.

6.7.5 Roof Drainage

The roof of the storage structure should be well drained. Downspout pipes should not enter or pass through the reservoir. Parapets, or similar construction, which would tend to hold water and snow on the roof, should be avoided.

6.7.6 Roof and Sidewall

The roof and sidewalls of all structures must be watertight with no opening except properly constructed vents, manholes, overflows, risers, drains, pump mountings, control ports, or piping for inflow and outflow.

a) Any pipes running through the roof or sidewall of a treated water storage structure must be welded, or properly gasketed in metal tanks. In concrete tanks, these pipes should be connected to standard wall castings which were poured in place during the forming of the concrete. These wall castings should have seepage rings imbedded in the concrete;

b) Openings in a storage roof or top, designed to accommodate control apparatus or pump columns, should be curbed and sleeved with proper additional shielding to prevent the access of surface or floor drainage water into the structure;

c) Valves and controls should be located outside the storage structure so that the valve stems and similar projections will not pass through the roof or top of the reservoir; and

d) The roof of concrete reservoirs with earthen cover should be sloped to facilitate drainage. Consideration should be given to installation of an impermeable membrane roof covering.

6.7.7 Vents

Finished water storage structures should be vented. Overflows should not be considered as vents. Open construction between the sidewall and roof is not permissible. The requirement for vents are as follows:

a) They should prevent the entrance of surface water and rainwater;

b) They should exclude birds and animals;

c) They should exclude insects and dust, as much as this function can be made compatible with effective venting. For elevated tanks and standpipes, four-mesh non-corrodible screen may be used; and

d) They should, on ground-level structures, terminate in an inverted U construction with the opening 600mm to 900mm above the roof or sod and covered with twenty-four mesh non-corrodible screen installed within the pipe at a location least susceptible to vandalism.

6.7.8 Frost Protection

All finished water storage structures and their appurtenances, especially the riser pipes, overflows, and vents, should be designed to prevent freezing which may interfere with proper functioning.

6.7.9 Internal Catwalk

Every catwalk over finished water in a storage structure should have a solid floor with raised edges so designed that shoe scrapings and dirt will not fall into the water.

6.7.10 Silt Stop

The discharge pipes from all reservoirs should be located in a manner that will prevent the flow of sediment into the distribution system. Removable silt stops should be provided.

6.7.11 Grading

The area surrounding a ground-level structure should be graded in a manner that will prevent surface water from standing within 15 m of the structure.

6.7.12 Corrosion Prevention/Reduction

Proper protection should be given to metal surfaces by paints or other protective coatings, by cathodic protective devices, or by both.

a) Paint systems should meet AWWA Standard D102 and NSF standard 61, and be acceptable to the reviewing authority. Interior paint must be properly applied and cured. After curing, the coating should not transfer any substance to the water which will be toxic or cause tastes or odours. Prior to placing in service, an analysis for volatile organic compounds is advisable to establish that the coating is properly cured. Consideration should be given to 100% solid coatings;

b) Wax coatings for the tank interior should not be used on new tanks. Re-coating with a wax system is discouraged; however, the old wax coating must be completely removed to use another tank coating; and

c) Cathodic protection should be designed and installed by qualified technical personnel and a maintenance contract should be provided.

6.7.13 Disinfection

a) Finished water storage structures should be disinfected in accordance with current AWWA Standard C652. Two or more successive sets of samples, taken at 24-hour intervals, should indicate microbiologically satisfactory water before the facility is placed into operation;

b) Disposal of heavily chlorinated water from the tank disinfection process should be in accordance with the requirements of the regulatory authorities;

c) A disinfection procedure (AWWA Standard C652 chlorination method 3, section 4.3) which allows use of the chlorinated water held in the storage tank for disinfection purposes is recommended where conditions warrant, (i.e., where water supply is not abundant, or where large reservoirs would require excessive volumes of water and chlorine.

6.7.14 Provisions for Sampling

Appropriate sampling points should be provided to facilitate collection of water samples for both bacteriologic and chemical analyses.

6.7.15 Adjacent Compartments

Finished water must not be stored or conveyed in a compartment adjacent to unsafe water when the two compartments are separated by a single wall.

6.7.16 Basins and Wet-wells

Receiving basins and pump wet-wells for finished water should be designed as finished water storage structures.

6.7.17 Standby Power

The necessity for standby power for a storage facility with pump discharge is dependent on whether the normal power is considered secure. In addition, the volume of elevated storage should be assessed when considering the requirements for standby power.

6.8 WATER TREATMENT PLANT STORAGE

6.8.1 Backwash Tanks

Backwash tanks should be sized, in conjunction with available pump units and finished water storage, to provide the required filter backwash water. Consideration should be given to the backwashing of several filters in succession.

6.8.2 Clearwell

Clearwell storage should be sized, in conjunction with distribution system storage, to relieve the filters from having to follow fluctuations in water use.

a) When finished water storage is used to provide contact time for chlorine (see Section 4.6) special attention must be given to size and baffling;

b) If used to provide chlorine contact time, sizing of the clearwell should include extra volume to accommodate depletion of storage during the nighttime for intermittently operated filtration plants with automatic high service pumping from the clearwell during non-treatment hours;

c) A minimum of two clearwell compartments should be provided;

d) The overflow pipe should be of sufficient diameter to permit the wasting of water in excess of the filling rate;

e) Consideration should be given to downgrade receiving areas of overflow water. Adequate surface detention should be provided to prevent soil erosion and to provide safe dissipation of chlorine; and

f) The discharge must not be directed to natural water bodies. Discharge in residential areas should be contained to appropriate and controlled storm water channels.

6.8.3 Adjacent Compartments

Finished water must not be stored or conveyed in a compartment adjacent to unsafe water when the two compartments are separated by a single wall.

6.8.4 Wet-Wells

Receiving pump wet-wells for finished water should be designed as finished water storage structures.

6.9 HYDROPNEUMATIC TANKS

The use of hydropneumatic (pressure) tanks, as storage facilities is preferred for small water supply systems. When serving more than 150 living units, however, ground or elevated storage is recommended in accordance with sizing requirements as outlined in section 6.4.

Pressure tank storage is not to be considered for fire protection purposes.

Pressure tanks should meet ASME code requirements or an equivalent requirement of provincial and local laws and regulations for the construction and installation of unfired pressure vessels.

6.9.1 Location

The tank should be located above normal ground surface and be completely housed.

6.9.2 Sizing

a) The capacity of the wells and pumps in a hydropneumatic system should be at least ten times the average daily consumption rate. The gross volume of the hydropneumatic tank in litres, should be at least ten times the capacity of the largest pump, rated in litres per minute. For example, a 750 L/min pump should have a 7,500 L pressure tank; and

b) Sizing of hydropneumatic storage tanks should consider the need for chlorine detention time, if applicable.

6.9.3 Piping

The tank should have bypass piping to permit operation of the system while it is being repaired or painted.

6.9.4 Appurtenances

Each tank should have a drain, and control equipment consisting of pressure gauge, water sight glass, automatic or manual air blow-off, means for adding air, and pressure operated start-stop controls for the pumps. In large tanks, where practical, an access manhole should be 600mm in diameter.

6.10 SECURITY/SAFETY

6.10.1 Access

Only trained and experienced workers should be allowed to work in water storage facilities.

Finished water storage structures should be designed with reasonably convenient access to the interior for cleaning and maintenance. For in-ground tanks at least two (2) manholes should be provided above the waterline at each water compartment where space permits.

Access manholes in above ground structures should be framed at least 100mm above the surface of the roof at the opening. For below ground structures access, manholes should be elevated a minimum 600mm above the top of covering sod;

a) Each of the manhole should be fitted with a solid watertight cover which overlaps the framed opening and extends down around the frame at least 50 mm;

b) Hinged at one side; and

c) Have a locking device.

6.10.2 Safety

The safety of employees must be considered in the design of the storage structure. As a minimum, such matters should conform to pertinent laws and regulations of the area where the reservoir is constructed.

a) Ladders, ladder guards, offset balconies, balcony railings, and safety located entrance hatches should be provided where applicable;

b) Elevated tanks with riser pipes over eight inches in diameter should have protective bars over the riser openings inside the tank; and

c) Railings or handholds should be provided on elevated tanks where persons must transfer from the access tube to the water compartment.

6.10.3 Protection

All finished water storage structures should have suitable watertight roofs which exclude birds, animals, insects, and excessive dust.

Fencing, locks and access manholes, and other necessary precautions should be provided to prevent trespassing, vandalism, and sabotage as per AWWA standards

Chapter 7.0 TRANSMISSION AND DISTRIBUTION SYSTEMS

Water distribution systems are made up of pipe, valves, and pumps through which treated water is moved from the treatment plant to domestic, industrial, commercial, and other customers. The distribution system also includes facilities to store water (see chapter 6), meters to measure water use, fire hydrants and other appurtenances. The major requirements of a distribution system is to supply each customer with sufficient volume of treated water at an adequate service pressure. Figure 7.1 indicates a typical transmission and distribution system.

7.1 DEFINITIONS

The following definitions are considered important for the purposes of this chapter.

7.1.1 Transmission Main

A transmission main is the pipeline used for water transmission, that is, movement of water from the source to the treatment plant and from the plant to the distribution system. (Water Transmission and Distribution Systems, AWWA, 1996).

Transmission mains typically do not have service connections.

7.1.2 Primary Distribution Main

A primary distribution main is a principal supply pipeline within a distribution system. A primary distribution main can also transport water to adjacent distribution networks.

7.1.3 Distribution Main

A distribution main is the local supply pipeline in the distribution system.

(Water Transmission and Distribution Systems, AWWA, 1996)

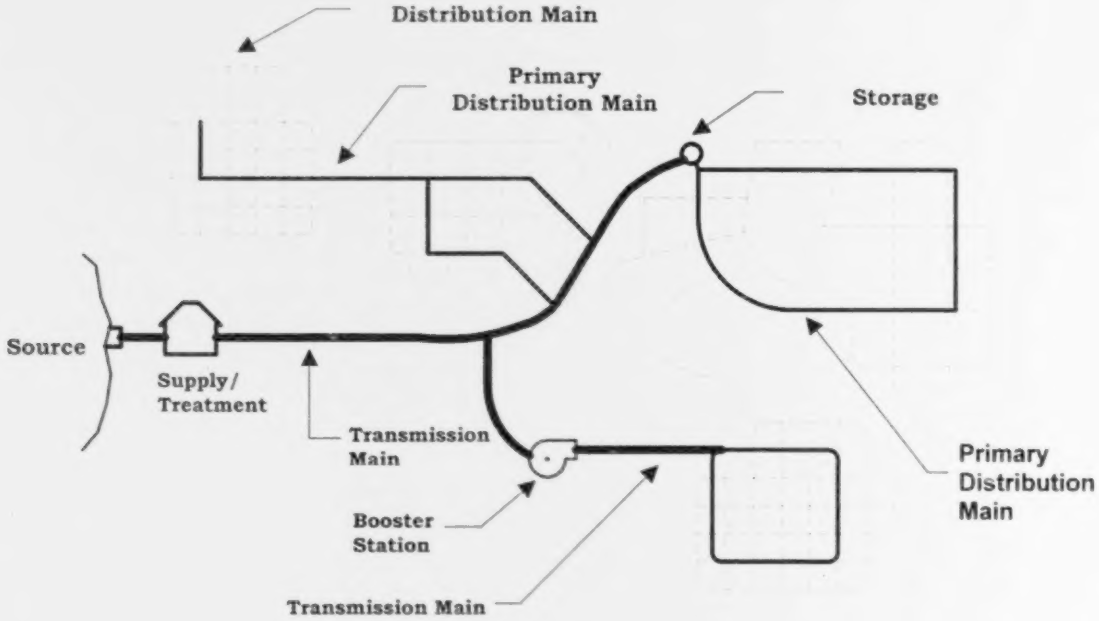

Distribution Main
Primary Distribution Main
Storage
Source
Supply/ Treatment
Transmission Main
Primary Distribution Main
Booster Station
Transmission Main

Figure 7.1: Transmission and Distribution Systems

7.1.4 Service Line (Lateral)

A service line is the pipe (and all appurtenances) that runs between the utility's water main and the customer's place of use, including fire lines.

(Water Transmission and Distribution Systems, AWWA, 1996)

7.1.5 Service Connection

A service connection is the portion of the service line from the utility's water main to the curb stop at or adjacent to the street line or the customer's property line.

(Water Transmission and Distribution Systems, AWWA, 1996)

7.1.6 Water Demands

- ***Average Day Demand*** is the average daily rate of flow of water in a year that must be supplied by the water system to meet customer demands.

- ***Maximum Day Demand*** is the largest daily rate of flow of water in a year that must be supplied by a water system, to meet customer demand.
- ***Peak Hour Demand*** is the largest hourly rate of flow of water in a year that must be supplied by a water system to meet customer demand.

- ***Minimum Hour Demand*** can also be referred to as the night demand. It is the lowest hourly rate of flow of water in a year that must be supplied to meet customer demand.

- ***Instantaneous Peak Demand*** is a short duration high water flow rate that can occur in a water supply system.

7.2 MATERIALS

There are a variety of materials in use within water transmission and distribution systems. Typical water pipe material used throughout the Atlantic Provinces include:

- Ductile Iron (DIP);
- Polyvinyl Chloride (PVC);
- High Density Polyethylene (HDPE); and
- Concrete Pressure Pipe.

7.2.1 Standards, Materials Selection

Pipe, fittings, valves and fire hydrants should conform to the latest standards issued by the CSA, AWWA, NSF, or NFPA, and be acceptable to the reviewing authority.

The proper selection of water pipe material should take into consideration the following:

- Working Pressure Rating;
- Surge Pressure Rating;
- Internal and External Corrosion Resistance;
- Negative Pressure Capability
- Ease of Installation;
- Availability;
- Pipe rigidity with regards to trench conditions; and
- Ease of repair.

7.2.2 Used Materials

Water mains which have been used previously for conveying potable water may be reused provided they meet the above standards and have been restored practically to their original condition.

7.2.3 Joints

Packing and jointing materials used in the joints of pipe should meet the standards of the CSA/AWWA and the reviewing authority. Pipe having mechanical joints or plain ends in combination with couplings having slip-on joints with rubber gaskets is preferred. Lead-tip gaskets should not be used. Repairs to lead-joint pipe should be made using alternative methods.

Flanged joints should only be used in conjunction with fitting such as valves within a properly constructed chamber.

7.2.4 Corrosion Prevention/Reduction

Special attention should be given to selecting pipe materials which will protect against both internal and external pipe corrosion. All products should comply with CSA/ANSI standards.

If soils are found to be aggressive, and the choice of materials is limited and subject to corrosion, action should be taken to protect the water main and fittings by encasement (wraps, coatings etc) and/or provision of cathodic protection. For small copper pipes, sacrificial anodes are recommended.

The design and installation of watermain encasements and cathodic protection should be as per the manufactures recommendations.

7.3 DESIGN CRITERIA – TRANSMISSION AND DISTRIBUTION SYSTEMS

7.3.1 Transmission and Distribution Pipelines

The design of water transmission and distribution mains requires special considerations of a number of key elements.

7.3.1.1 Transmission Mains

Transmission mains in water supply systems are typically large diameter, carry large flows under high pressure and are long in length, therefore the design activities should address:

- Sizing for ultimate future design flows;
- Sizing and layout to ensure adequate supply and turnover of water storage facilities;
- Elimination of customer service take-offs;
- Minimization of branch take-offs to help maintain flow and pressure control
- Air relief at high points and drain lines at low points;
- Isolation valving to reduce the length of pipe required to be drained in a repair or maintenance shut-down;
- Potential transient pressures; and
- Master metering.

7.3.1.2 Primary Distribution Mains

Primary distribution mains typically receives flow from transmission mains or pressure control facilities (booster pumps or pressure reducing valve) and supplies water to one or several local distribution systems as well as services to customers. The primary distribution main provides a significant carrying capacity or flow capability to a large area. Key design activities should address:

- Implementing a minimum "dual" feed system of primary distribution mains to supply large distribution systems;
- Looping and isolation valving to maintain services with alternate routing in the event of repair or maintenance shut-down;
- Area metering;
- Air relief at significant high points;
- Sizing for future extensions; and
- Elimination of dead-ends.

Distribution mains typically provide the water service to customers through a network of pipelines feed by the primary distribution mains. Key design activities should address:

- Looping and isolation valving to maintain service with alternate routing in the event of repair or maintenance shut-down;
- Adequate valving to provide an efficient flushing program;
- Elimination of dead-ends; and
- Pressure Surge Relief (requirements can be addressed by storage in the distribution system or other acceptable means).

7.3.2 Water Demands

The average day demand, maximum day demand, peak hour demand, minimum hour demand and instantaneous peak demand are defined in section 7.1.

Where values for maximum day demand, peak hour demand, and minimum hour (night) demand are not known they can be derived using peaking factors, i.e., applying numerical ratios of the average day demands.

Wherever possible, peaking factors based on actual usage records for a given water supply system should be used in the hydraulic analysis of a water transmission and distribution system. If however such records do not exist or are unreliable the following table can be used as a guide.

The peaking factors indicated contained in Table 7.1 are suitable for use in the hydraulic analysis of a municipal system with a variety of uses (residential /public /commercial /industrial). Water demands and peaking factors for systems containing appreciably large areas of commercial or industrial lands will require an evaluation of water demands based on individual facility users.

Table 7.1 Peaking Factors for Municipal Water Supply Systems

Equivalent Population	Minimum Hour Factor	Maximum Day Factor	Peak Hour Factor
500 to 1,000	0.4	2.75	4.13
1,001 to 2,000	0.45	2.50	3.75
2,001 to 3,000	0.45	2.25	3.38
3,001 to 10,000	0.50	2.00	3.00
10,001 to 25,000	0.60	1.90	2.85
25,001 to 50,000	0.65	1.80	2.70
50,001 to 75,000	0.65	1.75	2.62
75,001 to 150,000	0.70	1.65	2.48
Greater than 150,000	0.80	1.50	2.25

Source: Guidelines for the Design of Water Distribution Systems, Ontario 1985

Guideline average day water demand values can be referenced in the following documents:

- Modelling, Analysis and Design of Water Distribution Systems, Lee Cesario, 1995, AWWA;
- Design and Construction of Small Water Systems, 1999, AWWA;
- Nova Scotia Department of Environment and Labour, On-Site Sewage Disposal Systems, Technical Guidelines, Appendix F, November, 2000;
- MAYS, Larry W, Water Distribution Systems Handbook, 2000;
- Province of Ontario, Guidelines for the Design of Water Distribution Systems, 1985; and
- Johns Hopkins University and Office of Technical Standards.

7.3.3 Pressure

All transmission mains, primary distribution mains, distribution mains and service mains, including those not designed to provide fire protection, should be sized based on results of a hydraulic analysis of flow demands and pressure requirements.

Transmission and distribution mains should be designed to withstand the maximum working pressure plus pressure surge allowance. Mains should be tested to 1.5 times the working pressure, within a minimum of 75 psi and maximum of 175 psi.

The transmission and distribution system should be designed to maintain a minimum pressure of 275 kPa (40 psi) at ground level at all points in the distribution system under normal flow conditions. (Guidelines for the Design of Water Distribution System (MOE) Ontario, 1985).

Fire flow residual pressure should be maintained at 150 kPa (22 psi) at the flow hydrant, and should be a minimum 140 kPa (20 psi) within the system, for the design duration of the fire flow event.

The normal working pressure in the distribution system should be 410 kPa to 550 kPa (60 psi to 80 psi). The maximum design pressure during minimum demand periods should not exceed 650 kPa (95 psi). (GLUMRB, 1997).

7.3.4 Diameter

The minimum nominal diameter of pipe should be as follows:

- 200 mm for primary distribution mains (300 mm is recommended);
- 150 mm for distribution mains;
- 150 mm for service mains providing fire protection; and
- 100 mm for service mains not providing fire protection.

7.3.5 Velocity

The maximum design velocity for flow under maximum day conditions for transmission mains, primary distribution mains, distribution mains and service mains should be 1.5 m/s (5 ft/s). The maximum fire flow velocity should be 3.0 m/s (10 ft/s).

Flushing devices should be sized to provide a flow that provides a minimum cleansing velocity of 0.75m/s (≈2.5 ft/s) in the water main being flushed.

7.3.6 Dead Ends / Looping Requirements

Water distribution systems should be designed to exclude any dead-ended primary distribution mains, and distribution mains unless unavoidable. Appropriate tie-ins (loops) should be made wherever practical.

Where dead-end mains occur, they should be provided with a fire hydrant if flow and pressure are sufficient, or with an approved flushing hydrant or blow-off for flushing purposes. Flushing device should not directly connected to any sewer.

7.3.7 Fire Protection

All transmission mains, primary distribution mains and distribution mains, including those designed to provide fire protection, should be sized based on a hydraulic analysis to be carried out to determine flow demands and pressure requirements. The minimum size of water main for providing fire protection and serving fire hydrants should be 150mm (6 inch) diameter.

When fire protection is to be provided, system design should be such that fire flows and facilities are in accordance with the requirements of the appropriate

IAO Guidelines (see AWWA Manual M31 Distribution for Fire Protection, 1998. ISBN 0-89867-935-4).

7.3.8 Fire Pumps

NFPA 20 covers the selection of stationary pumps and installation of pumps supplying water for private fire protection. Items include:

- Water supplies;
- Suction;
- Discharge;
- Auxiliary equipment;
- Power supplies;
- Electric drive and control;
- Internal combustion engine drive and control;
- Steam turbine drive and control; and
- Acceptance tests and operation.

Stored water may be required to meet the demand for fire protection for a given duration. A reliable and 'safe' method of replenishment would be required (see chapter 6, Treated Water Storage Facilities).

7.3.9 Drain / Flushing Devices

Drain / flushing devices should be placed at significant low points in the transmission system. The drain/flushing devices are required to accommodate flushing during construction, and after a watermain break to drain the pipe for repair.

Where flushing devices are to be installed, they are to be designed in accordance with the requirements of AWWA C651 and due care with respect to: de-chlorinating; exit velocity of water during flushing (potential erosion/scour); minimum separation distance from nearest water-course; storage etc.

Flushing device should not be directly connected to any sewer.

7.3.10 Air Relief and Vacuum Valves

Air relief and vacuum valves should be installed, in a chamber, at significant high points in the transmission system and at other such locations as required for efficient operation of the water system.

Automatic air relief valves should not be used in situations where flooding of the manhole or chamber may occur.

The open end of an air relief pipe from automatic valves larger than 50 mm diameter should be extended at least 2.5 m (8 feet) above grade and provided with a screened and downward-facing elbow. The pipe from a manually operated valve should be extended to the top of the air relief chamber.

7.3.11 Flow Monitoring

Flow-monitoring devices and flow meters should be positioned at key locations along the transmission and primary distribution mains.

7.3.12 Crossing Obstacles

Due to geography, parallel services, etc., there will be a variety of physical obstacles which will result in watermain crossing obstacles. Considerations include, but are not limited to, the following.

7.3.12.1 Road Crossings

It is recommended for all new water mains crossing existing roads and all new roads crossing existing water mains that there is:

- A minimum cover of 1.5 m from the top of the pipe;
- Backfill method and material is approved;
- Drainage is adequate; and
- Ditches crossing water mains should provide minimum cover of 1.5 m or insulate for frost protection.

7.3.12.2 Sewers

See section 7.6.

7.3.12.3 Surface Water Crossings

Surface water crossings, whether over or under water, require special considerations. The reviewing authority should be consulted before final plans are prepared.

The pipe should be adequately supported and anchored, protected from damage and freezing, and accessible for repair or replacement.

A minimum ground cover of 600mm should be provided over the pipe. When crossing water-courses which are greater than 4.5 metres in width, the following should be provided:

- The pipe should be of special construction, having flexible, restrained or welded watertight joints;
- Valves should be provided at both ends of water crossings so that the section can be isolated for testing or repair; the valves should be easily accessible, not subject to flooding and should be within a properly constructed chamber; and

- Permanent taps should be made on each side of the valve within the manhole to allow insertion of a small meter to determine leakage and for sampling purposes.

7.3.12.4 Horizontal Drillings

Other methods of installation of watermains crossing obstacles or in deep installations include horizontal drilling/boring and installing pipe sections in protective sleeves.

7.3.13 Bedding

Bedding material and methodology should be approved by the reviewing authority and should be no less than as recommended by the pipe manufacture.

Note: **Do not** lay pipe and fittings when the trench bottom is frozen, under water or when trench conditions or weather are unsuitable.

7.3.14 Cover

All water mains should be covered with sufficient earth or other insulation to prevent freezing. If this is not possible then insulation around the pipe is required. In addition there is a requirement to have sufficient cover over water mains to minimize mechanical loading (see section 7.3.12.1). It is also recommended that maximum allowable depth be specified.

7.3.15 Thrust Restraint

All tees, bends, plugs and hydrants should be provided with reaction blocking, tie rods or restrained joints designed to prevent movement.

In situations where a watermain installation is above deep fills or parallel to a deep sewer, consideration should be given to using restrained joints.

7.3.16 Pressure and Leakage Testing

All types of installed pipe should be pressure tested and leakage tested in accordance with the latest edition of AWWA Standard C600, or as required by provincial or local authorities.

7.3.17 Disinfection

All new, cleaned or repaired water mains should be disinfected in accordance with AWWA Standard C651. The specifications should include detailed procedures for the adequate flushing, disinfection, and microbiological testing of all water mains. In an emergency or unusual situation, the disinfection procedure should be discussed with the reviewing authority.

7.3.18 Commissioning

Following successful testing and disinfection of watermains, the new system should be commissioned with due consideration of resulting pressure and flow changes and other parameters that may be experienced within the water supply system.

7.4 HYDRANTS

All fire hydrants and flush hydrants should be of **'self draining' Dry-Barrel type.** In areas having high water tables, appropriate measures should be taken to ensure drainage of the hydrant barrel (pumping or other suitable means).

Watermains not designed to carry fire-flows **should not have** fire hydrants connected to them.

7.4.1 Location and Spacing

Hydrants should be provided at each street intersection and at intermediate points between intersections as recommended by the Insurance Advisory Organization. In the absence of clear guidance hydrant spacing may range from 100 m to 175 m (≈ 325 to 600 feet) depending on the area being served and in accordance with IAO requirements.

7.4.2 Valves and Nozzles

Fire hydrants should have a bottom valve size of at least 125 mm (5 inch), one 113 mm (4.5 inch) pumper outlet and two 63 mm (2.5 inch) outlets.

Outlet and nozzle sizes should be standardized throughout the water distribution system.

Specific requirements should be coordinated with the local fire authority.

7.4.3 Hydrant Leads

The hydrant lead should be minimum of 150 mm (6 inch) in diameter. Shut-off valves should be installed in all hydrant leads.

7.4.4 Drainage

Attention must be given to drainage of sub-surface hydrant chambers, and only where unavoidable, should pumping chambers dry be specified. Where this is required the hydrants must be clearly marked as non-draining.

Hydrants may also require to be pumped dry when hydrant drains are plugged during freezing weather.

Hydrant drains consisting of a gravel pocket or dry well should be provided unless the natural soils will provide adequate drainage.

Hydrant drains should not be connected to or located within 3 m (10 ft) of sanitary sewers or storm drains.

7.5 VALVE AND METERING CHAMBERS

7.5.1 Chamber Construction

Chambers for air relief and vacuum valves, flow monitoring/measuring devices and pressure reducing valves should be:

- Constructed to provide a watertight structure with easy and safe access;
- Designed to include watertight gaskets where a pipe passes through a chamber wall; flexible rubber "A-Luk" type for cast-in-place concrete or mechanical expansion insert type for pre-cast concrete.
- Insulated to ensure adequate frost protection; and
- Include gravity or pump drainage.

7.5.2 Air Relief and Vacuum Valves Chambers

Air relief and vacuum valves should be installed, in a chamber, at significant high points in the distribution system and at other such locations as required for efficient operation of the water system.

Automatic air relief valves should not be used in situations where flooding of the manhole or chamber may occur.

7.5.3 Flow Measurement and Meter Chamber

Chambers containing flow monitoring/measurement devices should be located at off-road locations where feasible.

7.5.4 Pressure Reducing Valve Chambers

Pressure reducing valve chambers should be designed and constructed to provide:

- By-pass capability;
- Isolation valves on the upstream and downstream piping for the pressure reducing valve; and
- Upstream and downstream pressure gauges.

7.5.5 Chamber Drainage

Chambers should be drained, if possible, to the surface of the ground where they are not subject to flooding by surface water, or to underground absorption pits. Drains should be equipped with a backflow prevention device and screening to prevent the entry of insects, birds, and rodents.

In areas where high ground water levels are evident, above water table chambers should be considered.

7.6 SEPARATION DISTANCES TO SANITARY AND STORM SEWERS

The following factors should be considered in providing adequate separation:

- Materials and type of joints for water and sewer pipes;
- Soil conditions;
- Service and branch connections into the water main and sewer line;
- Compensating variations in the horizontal and vertical separations;
- Space for repair and alterations of water and sewer pipes; and
- Off-setting of pipes around manholes.

The requirements of the Atlantic Canada Standards for the Collection, Treatment and Disposal of Sanitary Sewage should be referenced.

7.6.1 Parallel Installation

Water mains should be laid at least 3 m (10 ft) horizontally from any existing or proposed sewer/pipe/MH. The distance should be measured edge to edge. In cases where it is not practical to maintain a 3 m separation, the reviewing authority may allow deviation on a case-by-case basis, if supported by data from the design engineer. Such deviation may allow installation of the water main closer to a sewer, provided that:

- The water main is laid in a separate trench;
- Or on an undisturbed earth shelf located on one side of the sewer; and
- At such an elevation that the bottom of the water main is at least 300 mm above the top of the sewer, or as required by local regulatory agencies.

(GLUMRB, 1997, NSDOE, 1992)

7.6.2 Crossings

Water mains crossing sewers should be laid to provide a minimum vertical distance of 450 mm between the outside of the water main and the outside of the sewer. This should be the case where the water main is either above or below the sewer with preference to the water main located above the sewer. At crossings, above or below, one full length of water pipe should be located so both joints will be as far from the sewer as possible (see NSDOE Specifications, 1992, GLUMRB, 1997). Special structural support for the water and/or sewer pipes may be required.

7.6.3 Forcemains

There should be at least 3 m horizontal separation between watermains and sanitary sewer forcemains. When crossing, the watermain should be above the forcemain with a vertical separation of a minimum 450 mm at the crossing.

The regulatory agency should be contacted in instances where existing infrastructure does not allow for the watermain to be placed above the forcemain at the required separation.

7.6.4 Manholes

Water pipe should not pass through or come in contact with any part of the sewer manhole.

7.6.5 Other Sources of Contamination

Design engineers should exercise caution when locating water mains at or near certain sites such as sewage treatment plants or industrial complexes. On site waste disposal facility including absorption fields must be located and avoided. The engineer should establish specific design requirements for locating water mains near any source of contamination and coordinate planned activities with the reviewing authority.

7.6.6 Exceptions

The reviewing authority must specifically approve any variance from the above requirements when it is impossible to obtain the specified separation distances. Where sewers are being installed and the above requirements cannot be met, the sewer materials should be waterworks grade 1000 kPa (≈150 psi) pressure rated pipe or equivalent and should be pressure tested to ensure water tightness.
(see GLUMRB, 1997, NSDOE guidelines, 1992).

7.7 CROSS CONNECTION CONTROL

7.7.1 Cross Connection Control Programs

There should be no connection between the distribution system and any pipes, pumps, hydrants, or tanks whereby unsafe water or other contaminating materials may be discharged or drawn into the system. Each water utility should have a program conforming to provincial requirements to detect and eliminate cross connections.

Where there is a requirement for water from the distribution system to be used as part of a process/procedure involving contaminants, measures must be taken to have discontinuous systems i.e. break-tanks with anti siphon filler pipes or fail-safe backflow devices. (See section 7.7.3 backflow prevention).

7.7.2 Interconnections

The approval of the reviewing authority should be obtained for interconnections **between** separate potable water supplies.

7.7.3 Back-Flow Prevention

Backflow prevention devices should be installed on consumer service connections where there is a high risk of contamination of the potable water supply system resulting from back flow or back pressure.

Local authorities should be contacted to determine specific cross connection control program requirements.

7.8 WATER SERVICES AND PLUMBING

7.8.1 Plumbing

Water services and plumbing should conform to relevant local and/or provincial plumbing codes, or to the applicable National Plumbing Code. Solders and flux containing more than 0.2% lead and pipe and pipe fitting containing more than 8% lead should not be used.

7.8.2 Consumer Connections (Laterals and Curb-Stops)

All consumer connections (laterals) should conform with the following:

- Minimum cover 1.6 m;
- Maximum cover 2.0 m;
- 300mm minimum horizontal and vertical separation distance from gravity sewer pipes;
- minimum 450 mm vertical separation when crossing above a sewer pipe;
- Minimum separation distance of 3 m from outdoor fuel tank;
- Minimum separation from sewage disposal field of 6 m;
- Single family residence connections should be minimum 20 mm (¾") copper or 25 mm high density polyethylene (HDPE) pipe. Large sizes may be required depending on length of lateral and grade elevations;
- Solder and flux containing more than 0.2% lead should not be used;
- Maximum velocity of flow should not exceed 4.5m/s (15 ft/s);
- There should be no joint between the curb stop and the building, if possible;

- A Shut-off valve (curb-stop) should be fitted on the street side of the property boundary;
- An approved metering device should be fitted;
- Backflow prevention devices, when required, should be installed after metering device;
- Shut-off valve should be fitted before the metering device; and
- Pressure reducing valves to be fitted as required before metering device (HRWC, 2003, GLUMRB, 1997)

7.8.3 Booster Pumps

Individual booster pumps should not be used for any individual service from the public water supply mains unless approved by the reviewing authority.

7.8.4 Service Meters

Each service consumer connection should be individually metered with an approved metering device.

7.8.5 Water Loading Stations

Water loading stations present special problems since the fill line may be used for filling both potable water vessels and other tanks or contaminated vessel. To prevent contamination of both the public supply and potable water vessels being filled, the following principles should be met in the design of water loading stations:

- A reduced pressure principle backflow prevention device should be installed on all watermains supplying water loading stations;
- The piping arrangement should prevent contaminant being transferred from a hauling vessel to other subsequently using the station; and
- Hoses should not be contaminated by contact with the ground.
- A loading station should be designed to provide access only to authorized personnel; and
- Access to a loading station should be strictly controlled to minimize water safety and security concerns.

7.8.6 Sampling Stations

Dedicated sampling stations may be required, within a water transmission and/or water distribution system, to collect water samples as part of the water quality monitoring program. The need for, and the proposed locations of sampling stations, should be discussed with the regulator.

Chapter 8.0 OPERATION AND MAINTENANCE

8.1 GENERAL

Operation and maintenance (O&M) manuals are specific to each project and should be produced for each project prior to commissioning.

Individual equipment will primarily be governed by the manufacturer's specifications for operation, maintenance and repair, and should be included in the O&M manual.

The O&M manual should be revised and updated as part of any major system improvement, including rehabilitation of any part or whole of existing infrastructure and the addition of new infrastructure.

The Utility should retain a current copy of the O&M manual at head office, and at individual facilities, for immediate access by the water utility personnel.

The O&M manuals should contain pertinent information on the normal day to day operation and maintenance of the facility and program schedules and descriptions of routine tasks.

Operations manuals should include up to date standard operating procedures and contingency plans.

8.2 SURFACE WATER SOURCE FACILITIES

8.2.1 Water Quality Documentation

Water quality monitoring, recording, and reporting should be in accordance with the requirements of the regulator. The manuals should include the procedures outlining the monitoring, recording and reporting requirements.

8.2.2 Operational Requirements

Operational requirements of a O&M manual for surface water sources should include, but not be limited to, the following:

- Water flow measurement;
- Water level measurement;
- Pump performance monitoring;
- Control valves;
- Record keeping;
- Schedule for review of data by qualified personnel;
- Diagnosis of problems; and

- Notifications requirements if there is a water quality problem.

8.2.3 Maintenance Requirements

Maintenance requirements for a O&M manual for surface water sources should include, but not be limited to, the following:

- Cleaning of screens;
- Cleaning of reservoirs and impoundments;
- Pump maintenance (see section 8.4); and
- Wet well cleaning.

8.2.4 Documentation

Documentation to be included in the O&M manual should include, but not be limited to, the following:

- Water levels and bathymetric data;
- Watershed boundary mapping;
- Watershed management and emergency spill response plans;
- Information on back-up supply (if any);
- Cleaning frequencies;
- Impoundment and reservoir specifications;
- Screen specifications;
- Pump specifications (see section 8.4); and
- Standard operating procedures and contingencies.

8.3 GROUNDWATER SOURCE FACILITIES

8.3.1 Water Quality Documentation

Water quality monitoring, recording, and reporting should be in accordance with the requirements of the regulator. The manuals should include the procedures outlining the monitoring, recording and reporting requirements.

8.3.2 Operational Requirements

Operational requirements of an O&M manual for groundwater sources should include, but not be limited to, the following:

- Water flow measurement;
- Water level measurement (production and monitoring wells);
- Submersible pump performance monitoring;
- On-off cycling of production wells;
- Sampling from monitoring wells;
- Control valves;
- Record keeping (including hydrograph);

- Schedule for review of data by qualified personnel;
- Diagnosis of problems; and
- Notification requirements if there is a water quality problem.

8.3.3 Maintenance Requirements

Maintenance requirements for a O&M manual for groundwater sources should include, but not be limited to, the following:

- Purging of production wells;
- Production well screen, or stabilizer screen cleaning/development;
- Monitoring well purging/cleaning/development;
- Submersible pump maintenance; and
- Disinfection.

For manufactured components (e.g., valves, meters) the preventative maintenance program will follow manufacturer's specifications.

8.3.4 Documentation

Documentation to be included in the O&M manual should include, but not be limited to, the following:

- Well log;
- Static water level from pumping test;
- Well specifications (depth, diameter, stabilizer, screen slot, setting and type);
- "As-built" well log showing relative positions of pump, screen, stabilizer, casing, etc.;
- Datum point from which all well measurements are made (e.g., casing collar); and
- Log of operating water level, flow rate and pump monitoring information; and
- Standard operating procedures and contingencies.

8.4 PUMPING FACILITIES

8.4.1 Operational Requirements

Operational requirements in the O&M manual for pumping facilities should include, but not be limited to, the following:

- Pump operating range;
- Operation of pumps at reduced flows;
- Priming;
- Final checks before starting pumps;
- Starting and stopping procedures for pumps;
- Auxiliary services on standby pumps;

- Restarting pumps after power failure;
- Record keeping;
- Monitoring devices (gauges and meters);
- Dehumidification;
- Drainage;
- Schematic of pump controls and monitoring devices; and
- Power supply schematic;
- Overall standard operating procedures; and
- Contingency plans.

8.4.2 Maintenance Requirements

Maintenance requirements for a O&M manual for pumping facilities should include, but not be limited to, the following:

- Daily observation of pump operation;
- Lubrication specifications;
- Semi-annual inspection;
- Annual inspections;
- Complete overhaul;
- Spare parts;
- Record keeping;
- Diagnosis of problems; and
- Out of service/lock out procedure.

8.5 WATER TREATMENT FACILITIES

8.5.1 Water Quality Documentation

Water quality monitoring, recording, and reporting should be in accordance with the requirements of the regulator and documented separately from the O&M manual.

8.5.2 Operational Requirements

Operational requirements of a O&M manual for water treatment plants should include, but not be limited to, the following:

- Raw and treated water flow measurement;
- Water level and pressure measurements (where applicable);
- Monitoring of online temperature, pH and individual filter effluent turbidities;
- Meter calibration;
- Sample collection and analysis;
- Laboratory jar testing procedures;

- Chemical receiving and preparation/mixing of day tanks;
- Chemical ordering;
- Adjustment of chemical feed rates;
- Changing of chlorine cylinders;
- Chlorine residual monitoring;
- Monitoring of filter headloss;
- Surface wash, backwashing and filter scraping;
- Media regeneration and/or filter ripening (if applicable);
- Clean-in place and pressure decay tests (membrane systems);
- Sludge level measurements and sludge removal (if necessary);
- Residuals treatment;
- Sludge dewatering;
- Schedule for review of data by qualified personnel; and
- Diagnosis of problems.

8.5.3 Maintenance Requirements

Maintenance requirements of a O&M manual for water treatment plants should include, but not be limited to, the following:

- Daily, semi-annual and annual inspections and testing procedures;
- Cleaning intervals and procedures;
- Preventative maintenance requirements;
- System overhaul intervals and procedures;
- Recommended spare parts inventory;
- Record keeping requirements;
- Out of service / lock out procedures; and
- General facility maintenance instructions.

Maintenance items should include, but not necessarily be limited to, the following systems:

- Online meters, monitors, level transmitters, pressure gauges, etc.;
- Pumping systems
- HVAC systems;
- Generators;
- Laboratory equipment;
- Chemical feed systems;
- Flocculation systems;
- Filter media;
- Process tankage;
- Membrane and pre-treatment systems;
- Valves, actuators and appurtenances;

- Residuals treatment systems;
- Dewatering systems;
- Sanitary waste systems;
- Storm sewer systems; and
- Service water systems.

Where maintenance and/or servicing of any of the above items are beyond the capability of the operator, the manual should indicate as such and should provide the appropriate contact information for servicing of that particular part and/or system.

8.5.4 Documentation

Documentation requirements to be specified in the O&M manual should include, but not be limited to, the following:

- Process diagram;
- Flow data;
- Required water quality data and chain-of custody forms;
- Level and pressure data;
- Up-to date spare-parts inventory;
- Record of inspections, testing and servicing for required systems;
- Upsets, problems and corrective action taken;
- Plant detailed design drawings and specifications;
- Maintenance schedules; and
- Back-up of all electronic information.

8.6 TREATED WATER STORAGE FACILITIES

8.6.1 Operation and Maintenance Requirements

Operational and maintenance requirements in the O&M manual for treated water storage facilities should include, but not be limited to, the following:

- Regular inspection;
- Temporary removal from service:
    - Draining;
    - Cleaning;
    - Repairs (including material specification); and
    - Disinfection.
- Return to service;
- Monitoring devices (gauges and meters); and
- Record keeping.

8.6.2 Cold Weather Operation

Treated water storage tanks can be severely affected by periods of cold weather, and it is essential that cold weather operation, maintenance and emergency procedures be addressed by the O&M manual.

8.7 TRANSMISSION AND DISTRIBUTION SYSTEMS

8.7.1 Operation and Maintenance Requirements

Operation and maintenance requirements in the O&M manual for transmission and distribution systems should include, but not be limited to, the following:

- Inspection;
- Valve exercising;
- Cleaning and Flushing;
- Disinfection;
- De-chlorination and discharge and of super chlorinated water;
- Repairs including emergencies and material specification;
- Surge protection;
- Monitoring devices (gauges and meters);
- Record Keeping;
- Preventative Maintenance;
- System mapping; and
- Leak detection and survey.

8.8 SMALL WATER SUPPLY SYSTEMS

Many of the requirements for operation and maintenance of small water supply system are covered in the previous sections of this chapter. The nature of small water supply systems, however, may require an O&M manual with a more 'holistic' approach, with less detail in some areas and greater detail in others.

Individual components of the system can be considered as units with operator requirements listed clearly, including monitoring, and specialized maintenance/repair requirements, for the most part governed by manufacturers specification and scheduling, which should be carried out by recognized/certified outside contractors.

The small water supply system O&M manual should include, but not be limited to, the following:

- Water Source;
- Intake;

- Pumping Facility (if applicable);
- Treatment;
- Disinfection;
- Water Storage;
- Distribution System;
- Monitoring;
- System Protection (including automated systems, alarms and response times);
- Operator Training and Supervision;
- Operator/Contractor Safety;
- Documentation; and
- Scheduling of Combined Operating and Maintenance Activities.

8.9 SAFETY

The O&M manual should address issues of worker safety, including, but not be limited to, the following:

- Working in slippery and wet conditions;
- Working in confined spaces;
- Working at elevated heights;
- Protective clothing and equipment;
- Safety harness operation;
- Ladders;
- Ventilation;
- Minimum Safe lighting;
- Minimum number of workers required for specific tasks;
- Lifting heavy objects;
- Procedures for excavation;
- Operator/Contractor Training;
- Operator/Contractor certification;
- Safety devices, including alarms; and
- Out of service/Lock out procedure.

8.10 OVERALL DOCUMENTATION

Documentation should be available for regular inspections, emergency servicing or rehabilitation of the facilities. The documentation should be available in an easily accessible location at each facility and at the utility head office.

The documentation should include, but not be limited to, the following:

- Operation and maintenance manuals for the facility and individual equipment;

- Name and phone numbers of utility/responsible engineer;
- Name and phone number of facility supervisor;
- Description and schematic facility and monitoring devices;
- Power supply information;
- Instructions for system shut-down; and
- Location of as-built drawings.

8.11 OPERATOR TRAINING SCHEDULING

A program for operator training should be developed and included in the operation and maintenance manual. The program should include reference to required periodic refresher courses.

The operator in charge of the utility should be responsible for ensuring this schedule is implemented and followed.

8.12 SCADA MONITORING

Where appropriate, the operation and maintenance manual should address SCADA monitoring.

All SCADA systems and components should be maintained as per the manufacture's specifications. All SCADA components that fail should be repaired or replaced on a timely basis.

A capability of manually checking SCADA data should be incorporated into all SCADA systems. SCADA measurements should be checked against manual measurements (e.g., pressure, flow values) on a regular basis to confirm the SCADA system is operating properly.

8.13 SECURITY

The operation and maintenance manuals should address security and protection of various facilities, including, where appropriate, including, but not limited to the following:

- Authorized access;
- Protection of the public from potential hazards within the facilities;
- Protection of water sources against contamination from negligence, accident, vandalism, terrorism etc.;
- Protection of water distribution system against contamination from negligence, accident, vandalism, terrorism etc.; and
- Protection of equipment from theft and vandalism.

Chapter 9.0 SMALL WATER SUPPLY SYSTEMS

9.1 GENERAL

The requirement of this manual is generally focused on the provision of 'municipal' water supply systems servicing urban and suburban areas. Other areas, however, may also have requirements for a central water supply system, but generally cannot benefit from the economies of scale provided with the construction of a large-scale project. This can preclude the development or extension of a full municipal water supply system, because the capital and operating costs may be prohibitive for the utility and/or the customer.

It is recognized that a small water supply can provide an acceptable level of service to customers. The system should be designed to a standard that is equivalent to municipal water systems, especially in terms of quantity and quality for normal consumption. The conditions for individual small water supplies, however, may differ significantly from municipal systems, and from each other, therefore strict adherence to these guidelines as outlined in the previous chapters may not always be possible.

This section is therefore included to provide guidance in the design of small water supply systems.

9.2 OUTLINE OF A SMALL WATER SUPPLY SYSTEM

Typical candidates for a small water supply include established communities and new small developments.

Established communities may consist of a community or village core with small lots and high housing density, and/or sprawling areas with large lots and low housing density.

A small water supply system may be required to service an established community because existing individual groundwater supplies have quality and/or quantity problems. Alternatively, an established community using a central source of water may require additional treatment processes, and/or a new central supply.

A small water supply system may be required to service a new development because the proposed development density precludes the use of individual wells. In addition, the cost of individual wells may be prohibitive.

Typically, new developments on a small water supply system may include, but not be limited to, the following:

- Clusters of rental recreational cottages;

- Condominium projects;
- Mobile home parks; and
- Small residential communities.

General features of a small water supply system include, but are not limited to, the following:

- Limited system redundancy;
- Small diameter piping; i.e., no fire protection;
- Operation and maintenance may be performed by part time staff, or contractors; and
- Technologies used often need to be relatively simple.

The regulatory agency should be contacted to determine site specific requirements for a small water system.

9.3 APPROVALS REQUIREMENTS

The approval requirement of small water systems is similar to the approval requirement of a municipal system. An abridged version follows, and Chapter 1 should be reviewed for a complete outline.

The proponent, however, should contact the regulator to determine if an Approval to Operate is required.

9.3.1 Pre-Consultation

Proponents planning a small water supply system should consult with the regulator to discuss the scope of the project and to determine the regulatory requirements.

9.3.2 Pre-Design Report

Where the established community or new development to be serviced is located close to a municipal supply, a pre-design investigation should be carried out to assess servicing options. Options to be assessed may include, but not be limited to, the following:

- Extension of an adjacent full municipal water supply system;
- Extension of a municipal system using reduced sized piping;
- Provision of a new full municipal water system;
- Provision of a new central small water supply using reduced sized piping; and
- Alternatives to central water supply.

Where the provision of a new central small water supply is the only option, the pre-design investigation should outline the following:

- Alternative Sources considered;
- Quantity of Option sources;
- Protection and Source Development;
- Intake Requirements;
- Gravity versus Pumping Supply;
- Water Quality of Option Sources;
- Water Treatment Requirements;
- Water Treatment Equipment Requirements;
- Storage Requirements;
- Transmission Main Requirements,
- Easement Issues;
- Operation Complexity
- Advantages and Disadvantages of Options;
- Capital Costs; and
- Operating Costs.

The completed pre-design report should be submitted to the regulator for review.

9.3.3 Review of Pre-Design Report

The pre-design report will be reviewed by the utility and the regulator. Allow 60 days or as specified by jurisdiction having authority, for review by the regulatory agency.

9.3.4 Acceptance of Pre-Design Report

The regulatory agency should indicate acceptance of the Pre-Design Report, and generally indicate whether there are any significant impediment to moving ahead with the detailed design and implementation of the proposed works. This should not be viewed as an approval to construct the proposed works.

9.3.5 Detailed Design Submission

The owner or authorized representative must prepare and submit an application and detailed design documents to the regulator for approval. The application should be signed by the owner.

Chapter 1 should be reviewed for the complete list of requirements. The regulator should be consulted for specific requirements when designing a small water supply system.

9.3.6 Review of Design Submission

A detailed design of the proposed waterworks, submitted with a formal application to the regulator, is required.

The application should refer to the pre-design report if applicable, and should include plans, specifications, a design brief, and other information as required by the regulator.

Where applicable, a processing fee form should be completed and the appropriate fee submitted.

The formal approval application, with the plans, specifications, and supporting documentation, should be submitted at least 90 days prior to the planned start of the construction or modification project. The plans, specifications and supporting documentation should be stamped with the seal and signature of a Professional Engineer that is licensed to practice in the Province of application. The application should be submitted to the regulator and should be signed by the owner, or a person representing the owner.

The regulator should review the application and detailed design documents to determine if it conforms to policies, standards, regulations, and guidelines enforced by the agency. During the review of the application, the regulatory agency may request oral or additional written information on the project. If requested information is not received, the regulator may declare the application incomplete, and advise the applicant of such.

9.3.7 Issue of Approval/Permit to Construct

An "Approval/Permit to Construct" should be issued by the regulator after the design application has been reviewed and found to be satisfactory. **The proponent should not undertake the proposed works until the official "Permit/Approval to Construct" has been issued.** (The Province of Prince Edward Island provides one approval only: Part I, Construction Requirements, and Part II, Operations).

The approval/permit should provide the owner with the authority to proceed with the construction of that particular project.

Any changes in the approved works specified in the application, must be submitted in writing to the regulator, and approved, in the form of an amendment to the approval/permit prior to construction.

9.3.8 Post Construction Report/Certificate of Compliance

A "Post-Construction Report/Certificate of Compliance" should be provided at the completion of the project. The report should contain all information regarding major changes from the approved plans or specification made during construction. These major changes include deviations which affect capacity, flow or operation of units.

9.3.9 Issue of Approval/Permit to Operate

The proponent should contact the regulator to determine if an Approval to Operate is required. Where applicable, the regulator should provide an "Approval/Permit to Operate" if all aspects of the project are acceptable.

The purpose of the permit is to clearly outline the operating and reporting requirements for the water supply system.

The expiry date of the approval/permit and the terms for renewal should be indicated by the regulatory agency.

9.4 WATER USE REQUIREMENTS

The sizing of the transmission main, primary distribution mains, distribution mains, and the water storage reservoirs in a municipal water supply system will generally be determined by the flow requirements for fire flow water. The "maximum day" and "peak hour" water uses are generally accommodated within the required pipe sizes, and are therefore not a significant factor in the sizing of the mains.

A small water supply system, however, will not normally include a fire flow component, and will therefore require a detailed assessment of water use in an effort to determine pipe sizes and storage requirements. It is essential that the source of supply, treatment equipment, transmission main, water distribution mains, and storage components is capable of meeting maximum and peak hour demands without overtaxing the source or resulting in excessive pressure loss in the distribution system.

9.4.1 Average Use

The projected water use demand, if not known, should be estimated from reliable records of present consumption in similar facilities serviced by water meters.

Where data is not available, "water use" tables as used in the respective provinces should be consulted for guidance.

If water use tables are not available, the following may be used as a guide for residential households:

- 1000 Litres per day (L/day) for a 3 bedroom home;
- 1200 L/day for a 3 bedroom home with high use fixtures;
- 1350 L/day for a 4 bedroom home; and
- 1500 L/day for a 4 bedroom home with high use fixtures.

Where approved by the regulator, water use for cottage and condominium developments may be calculated on the basis of the number of bedrooms. Notwithstanding the requirements outlined above, water use of 350 litres per day per bedroom, is recommended.

The above values represent the average flow over 24 hours. They do not reflect the maximum day and peak hour demands in the system, that will exceed the average value by a significant amount.

Small system communities that have commercial users have to be reviewed in detail to resolve problems associated with high variant system demand.

9.4.2 Maximum Day Demand

Maximum day demand is the minimum flow for which a small water system should be designed. The characteristics of a small rural water system, however, require special consideration. As with municipal water systems it may be possible to derive a value for maximum day demand, based on a small water system of similar size and consumer characteristics, in an adjacent or nearby development.

In the absence of reliable data, the maximum daily flow may be calculated on the basis that the average daily flow occurs over an eight-hour period. This equates to a maximum day factor of three times average day.

9.4.3 Peak Hour Demand

As with maximum day demand, it may be possible to derive this value, based on nearby or adjacent developments with similar characteristics. In the absence of actual data, however, the peak hour demand may be determined by taking the average daily flow divided by 24 hours, and multiplying it by the appropriate peak rate factor obtained in Table 9.1.

Table 9.1 Peak Factors for Small Water Supply Systems

Dwelling Units Serviced	Equivalent Population	Night Minimum Hour Factor	Maximum Day Factor	Peak Hour Factor
10	30	0.1	9.5	14.3
50	150	0.1	4.9	7.4
100	300	0.2	3.6	5.4
150	450	0.3	3	4.5
167	500	0.4	2.9	4.3

Source: Based on Figure 1, Guidelines for the Design of Seasonally Operated Water Supply System, Ontario, 1985 (MOE).

For a system with 10 homes, the peak hour factor is 15 and for a system with 200 homes the peak hour factor is 4. While the peaking factors may seem large, the actual volume of water that is required may be quite small and water storage for balancing may be very feasible and cost effective.

9.4.4 Outdoor Use

Where applicable, an allowance for outdoor use of water (lawn watering, car washing) should be made. It should be assumed that a maximum of 25% of the homeowners would be using an outdoor tap at any one time at the rate of 20 L/min for one hour per day. (This allowance is not required if the distribution system is designed to provide fire protection).

9.4.5 Fire Protection

By definition, a small water system is not normally designed to provide fire protection.

9.5 SOURCE OF SUPPLY

The design engineer should demonstrate that an adequate quantity of water is available to meet the demands of the small water supply system.

9.5.1 Surface Water

Subject to the source and the requirements of the regulator, a hydrology study by a professional hydrologist may be required to confirm the availability of water.

The reliable yield of the source, after the flow has been regulated by seasonal balancing storage, should be adequate to supply the maximum day demand during moderate dry periods. A moderate dry period is considered to be a low stream flow with a return period of twenty-five years.

9.5.1.1 Impounding Reservoirs

Impounding reservoirs should be designed to minimize the deterioration of raw water quality. This is done by minimizing contact with organic material, (grass, peat, trees etc.) avoiding shallow water areas, and embankment erosion.

9.5.1.2 Intakes

Intake works should be designed to optimize water quality, minimize maintenance and adverse environmental impacts. They should not obstruct the passage of vessels in navigable waters.

Intakes should be sized to the ultimate capacity of the waterworks system to limit disturbance to the aquatic environment. Screens should be easy to clean and designed to meet requirements of the Department of Fisheries and Oceans regulations.

River intakes should be sited in a stable reach of the river channel, in sections where erosion or deposition will not endanger the works, and in such a way that the natural regime of the river will not be disturbed.

Submerged intake pipes in rivers and lakes should be graded to prevent accumulation of gasses, and be adequately anchored and buried. Provision should be made to remove sediment from the pipe by incorporating a back-flushing device.

Intake works should be protected against unauthorized persons and contamination from domestic, industrial or other harmful wastes or runoff. The intake works should be reasonably accessible in all seasons, and should be protected from accumulation of ice.

9.5.1.3 Raw Water Pumps

When raw water is supplied by pumping, at least two pumping units should be installed. With any pump out of service the remaining pump(s) should be capable of maintaining maximum day demand within the small water supply system.

Pumping facilities should be designed to maintain the sanitary quality of the pumped water. Pumping stations should be above ground and protected from flooding.

Operation of the pumps should be regulated by utilizing high and low level sensing devices located in the treated water storage reservoir.

The operation or pumps in a constant pressure system should be regulated by pressure switches.

9.5.2 Groundwater

Wells should be located, constructed, tested and disinfected in accordance with Section 2, or as required by the regulator.

The well should be protected from possible sources of contamination with respect to land use adjacent to the well and the recharge area of the well.

A well protection plan may be required by the regulator.

9.5.2.1 Number of Wells

Where more than 20 homes are served, at least two production wells should be used, each being capable of providing the maximum daily demand. Both wells should be on-line and alternating in use.

If the individual wells are not capable of providing the maximum day demand, at least one day's storage should be provided.

Where less than 20 homes are serviced, and/or only one well is used, it is recommended that a spare replacement pump be available.

9.6 WATER TREATMENT

All drinking water should meet applicable drinking water standards and/or guidelines.

Surface water and groundwater under the direct influence of surface water (GUDI), where applicable, will require filtration and disinfection to meet drinking water standards and guidelines.

Groundwater may require treatment to address specific individual health or aesthetic based water quality parameters.

It is recognized, however, that redundancy requirements in small water systems may be cost-prohibitive. The proponent, in this regard, may present innovative options to the regulator for consideration. In addition, it is recommended that management plans and standard operating procedures and contingencies be in place to deal with the reduced capacity and water quality maintenance requirements.

The regulator may consider system specific exceptions, and may require the provision of emergency water storage and/or emergency shutdown of the water system or part of the system in the event of a treatment system malfunction.

The provision of water storage at a suitable elevation may negate some redundancy requirements.

9.6.1 Treatment of Surface Water

Parameters of concern in the treatment of surface water include, but are not limited to, the following:

- Colour;
- Turbidity;
- Aggressiveness;

- Iron;
- Manganese; and
- Dissolved Organic Carbon.

The pre-design investigation should evaluate the treatability of the water using laboratory and/or pilot scale testing. Chapter 2 outlines the requirements.

The basic components for water treatment of surface water are outlined in Chapter 4 and consists of the following:

- Presedimentation;
- Coagulation and Flocculation;
- Clarification;
- Filtration; and
- Disinfection.

Proprietary treatment equipment may be considered for treatment of surface water.

9.6.1.1 Disinfection of Surface Water

All surface water sources and GUDI supplies shall be disinfected.

9.6.2 Treatment of Groundwater

Groundwater may require treatment for specific parameters such as hardness, iron, manganenese, and arsenic. Proprietary treatment units will typically be used.

9.6.2.1 Disinfection of Groundwater

Barring system specific exceptions, groundwater shall be disinfected.

9.6.3 Methods of Disinfection

Chlorination is the recommended method of disinfection for a small water supply system, as it provides a measurable residual in the distribution system. The presence of a measurable chlorine residual is typically an indication that the bacteriological quality of the water is acceptable.

The use of a hypochlorination system is the preferred method of chlorination for small water supply system because it is easy to operate and maintain.

Hypochlorination may be accomplished with a sodium or calcium hypochlorite solution. The facilities should include a cool, dark, dry, clean, above ground and vented area for the storage and for the use of hypochlorite disinfectant. The facilities should also include covered make-up and feed solution tanks.

The use of gas chlorination facilities is not recommended. Gas chlorination should be restricted to water systems where qualified operators are available to operate and maintain the equipment on an ongoing basis, and who are trained and equipped to handle any emergency.

Requirements for chlorine contact time and free chlorine residuals have to be considered when planning and locating the disinfection facilities.

Ultraviolet (UV) disinfection may be used when a measurable residual is not required in the water distribution system (groundwater system). When UV disinfection is used, chlorination may be required periodically to disinfect the distribution system.

9.7 AUXILIARY POWER

An auxiliary power supply may not be feasible for a small water supply system. In the event of a prolonged power outage, options include hauling water or the provision of a mobile generator.

9.8 WATER STORAGE

Finished water storage facilities should have sufficient capacity to balance the fluctuations in domestic demands and minimize pump start/stop cycles. This storage should be reliably available, preferably by gravity. If site conditions preclude gravity flow, a secondary pumping system will be required.

9.8.1 Storage Capacity

Storage should be provided for balancing and emergency use. Unless otherwise determined by engineering studies, storage to control pumps, balance fluctuations in domestic demand and stabilize pressures, should not be less than 25% of maximum day demand. Also emergency storage should not be less than 25% of maximum day demand.

In instances where the yield of the source is limited, a minimum one day storage is recommended. Where applicable, an allowance should also be made for backwash water requirements.

9.8.2 Water Storage Materials

Water storage facilities for small water supply systems are typically constructed from pre-cast or cast-in-place concrete, fibreglass or steel.

9.8.3 Treated Water Pumps

Where water is provided from a treated water storage tank, at least two high lift pumps should be provided. Each pump should be capable of delivering a minimum of the design maximum day demand at the desired pressure.

To deliver the peak hour water demand it may be necessary to operate more than a single pump.

9.8.4 Acceptable Pressure

Pressures within a small rural supply system should generally be maintained between 275 kPa to 420 kPa (40 to 60 psi).

9.9 PRESSURE TANKS

Pressure (hydropneumatic) tanks are normally used as a means of providing pump control, but not for providing balancing and emergency storage. There are however occasions, for small rural water supply systems, when pressure tanks can be used to provide balancing and emergency storage. Authorization from the regulator should only be given upon receipt of an acceptable detailed design from a professional engineer

9.10 WATER DISTRIBUTION SYSTEM

9.10.1 Material

The selection of pipe material for waterlines in a small water supply system should be carried out as per the recommendations in Section 7.2.

9.10.2 Distribution System Piping Diameter

The distribution system piping diameter should be sized to provide adequate pressures and velocities at peak hour demand.

9.10.3 Pressure Rating

The minimum recommended pressure rating for piping in a small water system network is 900 kPa (175 psi).

9.10.4 Velocities

Velocities in the water distribution system should be a maximum of 1.5 m/s (5 ft/s).

9.10.5 Service Connections

Service connections should be a minimum 19 mm (¾ inch) diameter.

9.10.6 Water Meters

It is preferred that individual water meters be installed at all customers. Where this is not feasible, a master water meter should be located at the source.

9.10.7 Hydrants

Hydrants are not to be connected to small rural water supply systems not designed for fire flows.

9.10.8 Individual Home Booster Pumps

Individual home booster pumps should not be connected to a small water system unless specifically authorized.

9.11 MONITORING REQUIREMENTS

Monitoring and reporting requirements, where it is the responsibility of the utility, should be outlined by the regulator in the Approval/Permit to Operate.

The monitoring program should be carried out in compliance with sampling and analysis requirements outlined in the approval/permit.

In instances where monitoring is the responsibility of a regulator, reporting will be the responsibility of the regulator and/or laboratory.

9.12 FACILITY CLASSIFICATION AND OPERATOR CERTIFICATION

It is recommended that operators of small water supply systems be thoroughly trained in all aspects of the operation and maintenance of the water supply system, and provided with all necessary manuals and system documentation.

Some jurisdictions have adopted regulations that makes facility classification and operator certification mandatory while others strongly recommend operator certification. Where applicable, the regulations require all water treatment and water distribution personnel to be certified, and require that an operator with a certification level equivalent or greater to the facility classification be in direct responsible charge.

The regulator should be consulted regarding specific requirements.

9.13 EASEMENTS, STATUTORY RIGHTS OF WAY, AND RESTRICTIVE COVENANTS

An easement should be provided when any part of a small water supply system is to be located on privately owned land (other than service connections). The easement should be registered in favour of the water supply system authority in perpetuity. The minimum practical width of easement should be 6 metres.

APPENDIX A

Reference

1. Alberta Environmental Protection (Dec., 1997) *Standards, and Guidelines for Municipal Waterworks, Wastewater and Storm Drainage Systems.*

2. Arora, H.; Giovanni, G. and LeChevallier, M. (2001). *Spent Filter Backwash Water Contaminants and Treatment Strategies. Jour. AWWA*, 93, 5, 100-112.

3. AWWA (1990). *Water Quality and Treatment: A Handbook of Community Water Supplies.* McGraw-Hill, Inc., Toronto, ON.

4. AWWA/ASCE (1998). *Water Treatment Plant Design.* McGraw-Hill, Inc., Toronto, ON.

5. AWWA (1998). *AWWA Standard for Water Wells.* ANSI/AWWA A100-97. Feb 1,1998.

6. AWWA/ASCE/USEPA (1996). *Technology Transfer Handbook: Management of Water Treatment Plant Residuals.* American Water Works Association and the American Society of Engineers.

7. Biershenk, W.H. (1964). Determining Well Efficiency by Multiple Step Drawdown Tests. Int. Assoc. of Scientific Hydrology No. 64: 493-507.

8. Canadian Association of Environmental Analytical Laboratories/Standards Council of Canada (CAEAL/SCC

9. Canadian Ground Water Association, 1995. Guidelines for Water Well Construction.

10. Cooper, H.H. & C.E. Jacob (1946). A Generalised Graphical Method For Evaluating Formation Constants and Summarising Well Field History. Trans Amer. Geophysical Union 27, pp. 526-534.

11. Cornwell, D. and Lee, R. (1994) *Waste Stream Recycling: Its Effects on Water Quality. Jour. AWWA*, 86, 11, 50-63.

12. Cornwell, D. et al. (2001) *Treatment Options for Giardia, Cryptosporidium and Other Contaminants in Recycled Backwash Water.* American Water Works Association Research Foundation, Denver, Colorado, USA.

13. Cornwell, D. and MacPhee, M. (2001) *Effects of Spent Filter Backwash Recycle on Cryptosporidium Removal. Jour. AWWA*, 93, 4, 153-162.
14. Droste, R.L. (1997). *Theory and Practice of Water Treatment.* John Wiley &

Sons, Toronto, ON.

15. Edzwald, J. (1995) *Principles and Applications of Dissolved Air Flotation. Water Sci. Tech.*, 31, 3-4, 1-23.

16. Edzwald, J. et al. (2001) *Impacts of Filter Backwash Recycle on Clarification and Filtration.* American Water Works Association Research Foundation, Denver, Colorado, USA.

17. Environment Canada (2000). *Atlantic Canada Standards and Guidelines Manual for the Collection, Treatment and Disposal of Sanitary Sewage.* Environment Canada, Ottawa, ON.

18. Faust, S.D. and Aly, O.M. (1998). *Chemistry of Water Treatment.* Ann Arbour Press, Chelsea, MI, USA.

19. Government of Newfoundland and Labrador. *Guidelines for the Design, Construction & Operation of Water & Sewerage Systems.*

20. Great Lakes Upper Mississippi River Board of State Public Health and Environmental Managers (GLUMRB) (1997). *Recommended Standards for Waterworks.* Health Education Services, A Division of Health Research, Inc., Albany, NY, USA.

21. Hantush, M.S. and C.E. Jacob, (1955). Non-Steady Radial Flow in an Infinite Leaky Aquifer. Trans. Amer. Geophysical Union 36: 95-100.

22. Health Canada (1993). *Guidelines for Canadian Drinking Water Quality Supporting Documentation: Trihalomethanes.*

23. Health Canada (1993). *Water Treatment Principles and Applications: A Manual for the Production of Drinking Water.*

24. Health Canada (1996). Guidelines for Canadian Drinking Water Quality, 6th Ed. Prepared by Federal-Provincial Subcommittee on Drinking Water of the Federal-Provincial Committee on Environmental and Occupational Health. Canada Communications Group Pub., Ottawa, Canada. 90 p.

25. Health Canada, 2003. Summary of Guidelines for Canadian Drinking Water Quality. Prepared by Federal-Provincial Subcommittee on Drinking Water of the Federal-Provincial Committee on Environmental and Occupational Health. Annual Up-dates.

26. Hendricks, D. et al. (1991) *Manual of Design for Slow Sand Filtration.* American Water Works Association Research Foundation, Denver, Colorado, USA.
27. Kawamura, S. (2000). *Integrated Design of Water Treatment Facilities.* John Wiley & Sons, Toronto, ON.

28. Kirmeyer, G. L. et al. (1999). *Maintaining Water Quality in Finished Water Storage Facilities.* American Water Works Association Research Foundation, Colorado, USA.

29. Masschelein, W.J. (1992). *Unit Processes in Drinking Water Treatment.* Marcel Dekker, Inc., New York, NY.

30. Ministry of Ontario Environment (Mar., 1985) *Guidelines for the Design of Water Supply Systems for Small Residential Developments.*

31. Ministry of the Ontario Environment, (Mar., 1987) *Chlorination of Potable Water Supplies.*

32. Montgomery, J.M., Consulting Engineers (1985). *Water Treatment Principles and Design.* John Wiley & Sons, Toronto, ON.

33. Prince Edward Island Department of Fisheries, Aquaculture and Environment. *10 Points to Purity.*

34. New Brunswick Department of the Environment and Local Government. *Watershed Protection Area Designation.*

35. New Brunswick Department of the Environment and Local Government. *Wellfield Protection Area Designation Order.*

36. Nova Scotia Department of the Environment and Labour (Jan. 2002), *Surface Water Treatment Standard.*

37. Nova Scotia Department of the Environment and Labour, (Feb. 2003), *Groundwater Water Treatment Standard.*

38. Nova Scotia Department of the Environment and Labour, (Dec. 2002). *Protocol for Determining Groundwater Under the Direct Influence of Surface Water.*

39. Nova Scotia Department of the Environment and Labour, (Dec. 2002).

Guidelines for Monitoring Public Drinking Water Supplies.

40. Nova Scotia Department of the Environment and Labour. NSDEL (Dec. 2002). *Municipal Approval Process, Points of Clarification.*

41. Nova Scotia Department of the Health (Jun. 1983). *Guidelines for Installation of Gas Chlorination Systems.*

42. Theis, C.V. (1935) The Relationship Between the Lowering of the Piezometric Surface and the Rate and Duration of Discharge of a Well using Groundwater Storage. Trans. Amer. Geophysical Union 2, pp. 519-524.

43. United States Environmental Protection Agency (2001) *National Primary Drinking Water, Filter Backwash Recycle Rule; Final Rule: Federal Register, 66, 11.*

44. United States Environmental Protection Agency (June 2003) *Draft Ultraviolet Disinfection Guidance Manual.* United States Environmental Protection Agency, Office of Water, Washington, DC.